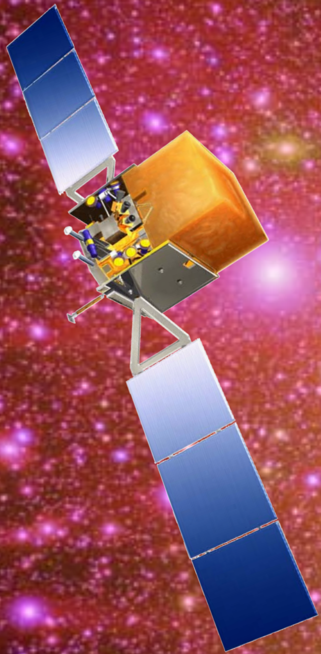
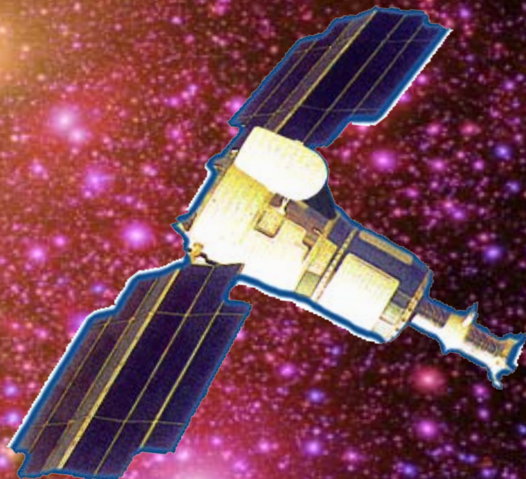
Indirect dark matter search with cosmic-rays signals





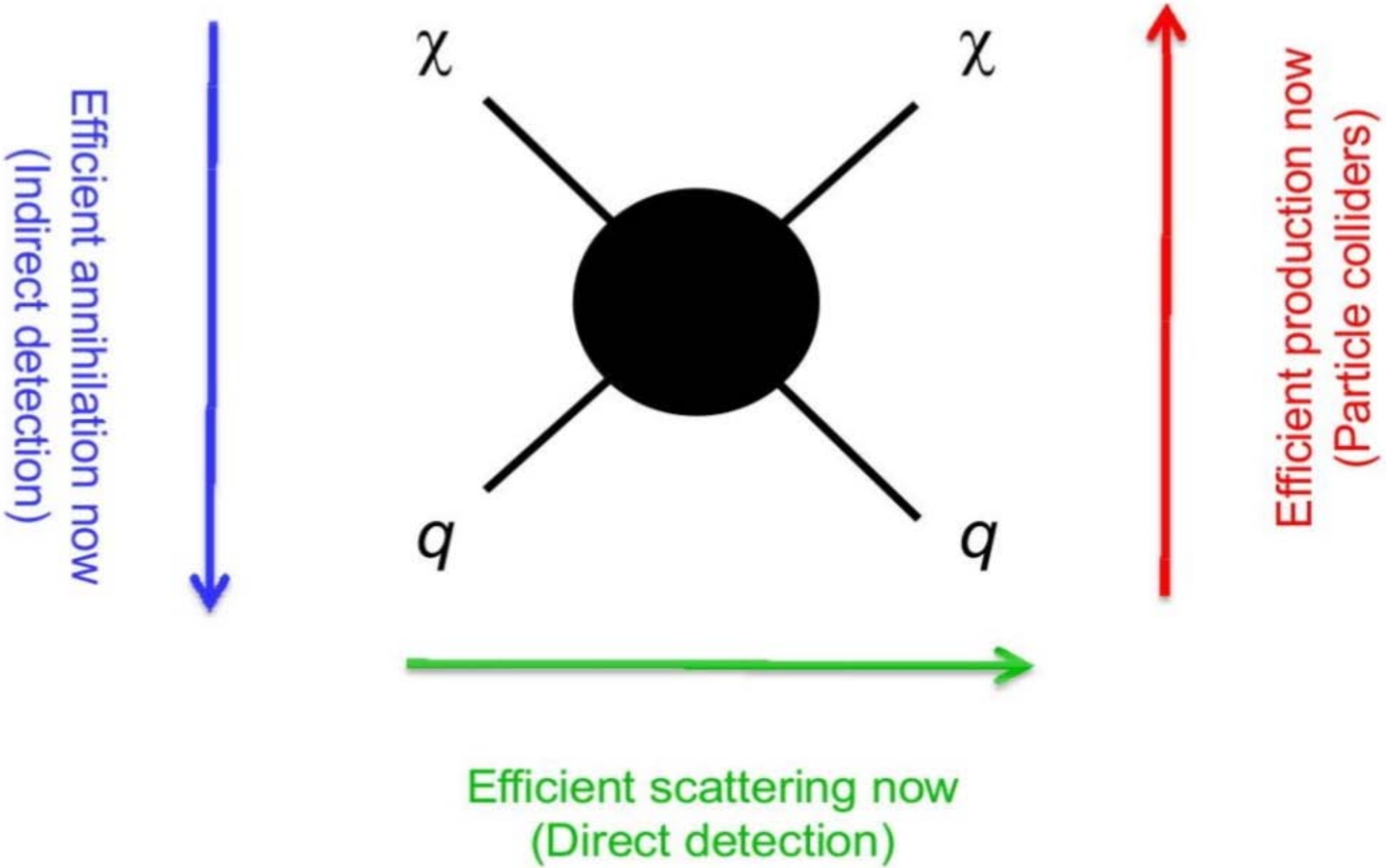
Aldo Morselli

INFN Roma Tor Vergata

2010 June 23

Electron-Nucleus Scattering XI **Elba Workshop**

Marciana Marina, Isola d'Elba, Italy.

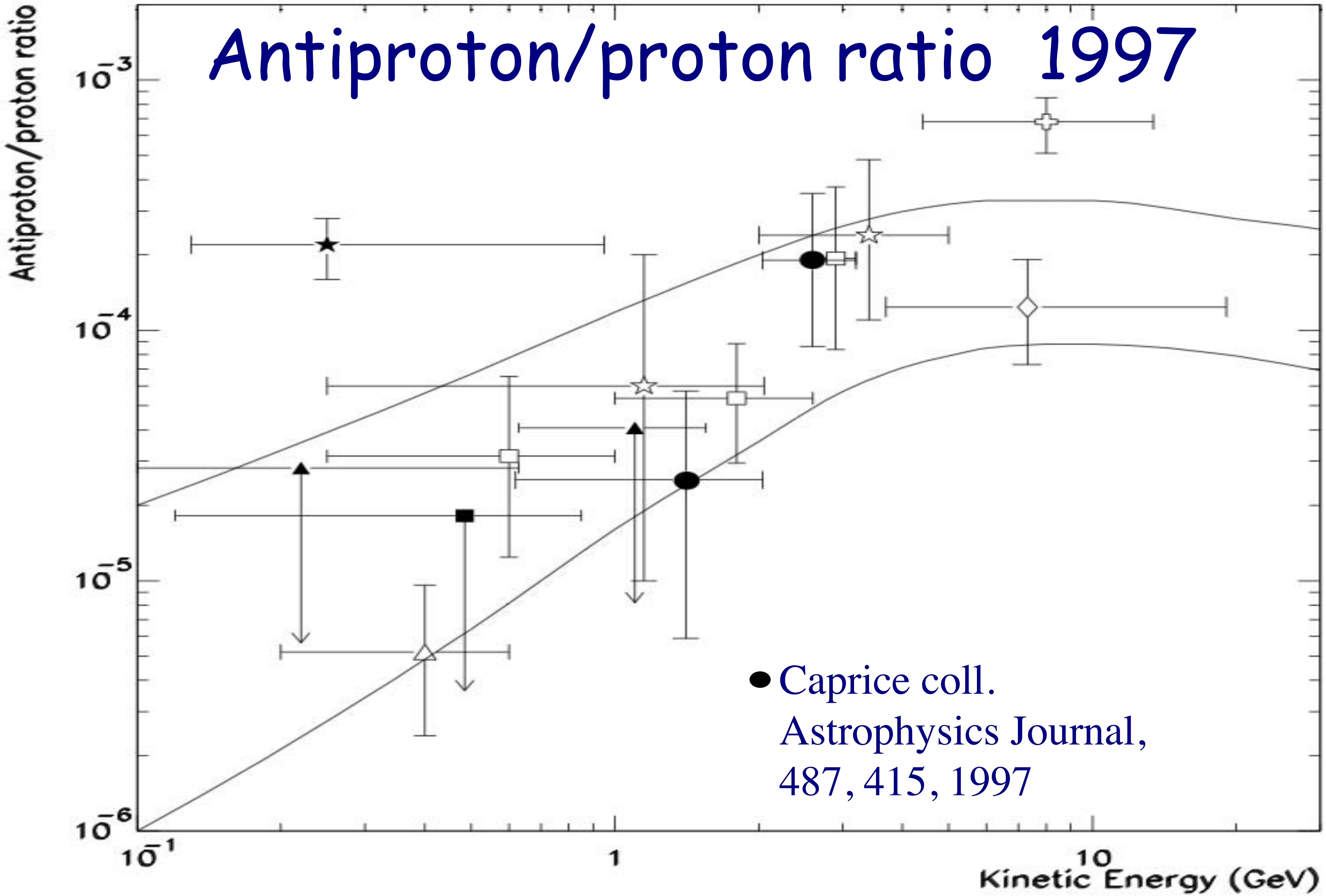

χ
χ
q
q
Efficient annihilation now
(Indirect detection)
Efficient production now
(Particle colliders)
Efficient scattering now
(Direct detection)

Neutralino WIMPs

Assume χ present in the galactic halo

- χ is its own antiparticle **=>** can annihilate in galactic halo producing gamma-rays, antiprotons, positrons….
- Antimatter not produced in large quantities through standard processes (secondary production through p + p **-->** anti p + X)
- So, any extra contribution from exotic sources ($\chi\,\chi$ annihilation) is an interesting signature
- ie: $\chi\,\chi$ --> anti p + X
- Produced from (e. g.) $\chi\,\chi$ **-->** q / g / gauge boson / Higgs boson and subsequent decay and/ or hadronisation.

Antiproton/proton ratio 1997



● Caprice coll.
Astrophysics Journal, 487, 415, 1997

Propagation Equation for Cosmic Rays

$$\frac{\partial \psi(\mathbf{r},p,t)}{\partial t} = q(\mathbf{r},p) + \nabla \cdot (D_{xx}\nabla\psi - \mathbf{V}\psi) + \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p} \frac{1}{p^2} \psi - \frac{\partial}{\partial p}\left[\dot{p}\psi - \frac{p}{3}(\nabla \cdot \mathbf{V})\psi\right] - \frac{1}{\tau_f}\psi - \frac{1}{\tau_r}\psi$$

convection velocity field that corresponds to galactic wind and it has a cylindrical symmetry, as the geometry of the galaxy. It's z-component is the only one different from zero and increases linearly with the distance from the galactic plane

diffusion coefficient in the impulse space, quasi-linear MHD:

$D_{pp}(D_{xx}, v_A)$

loss term: fragmentation

loss term: radioactive decay

diffusion coefficient is function of rigidity

$$D_{xx} = \beta D_0 (\rho/\rho_0)^\delta$$

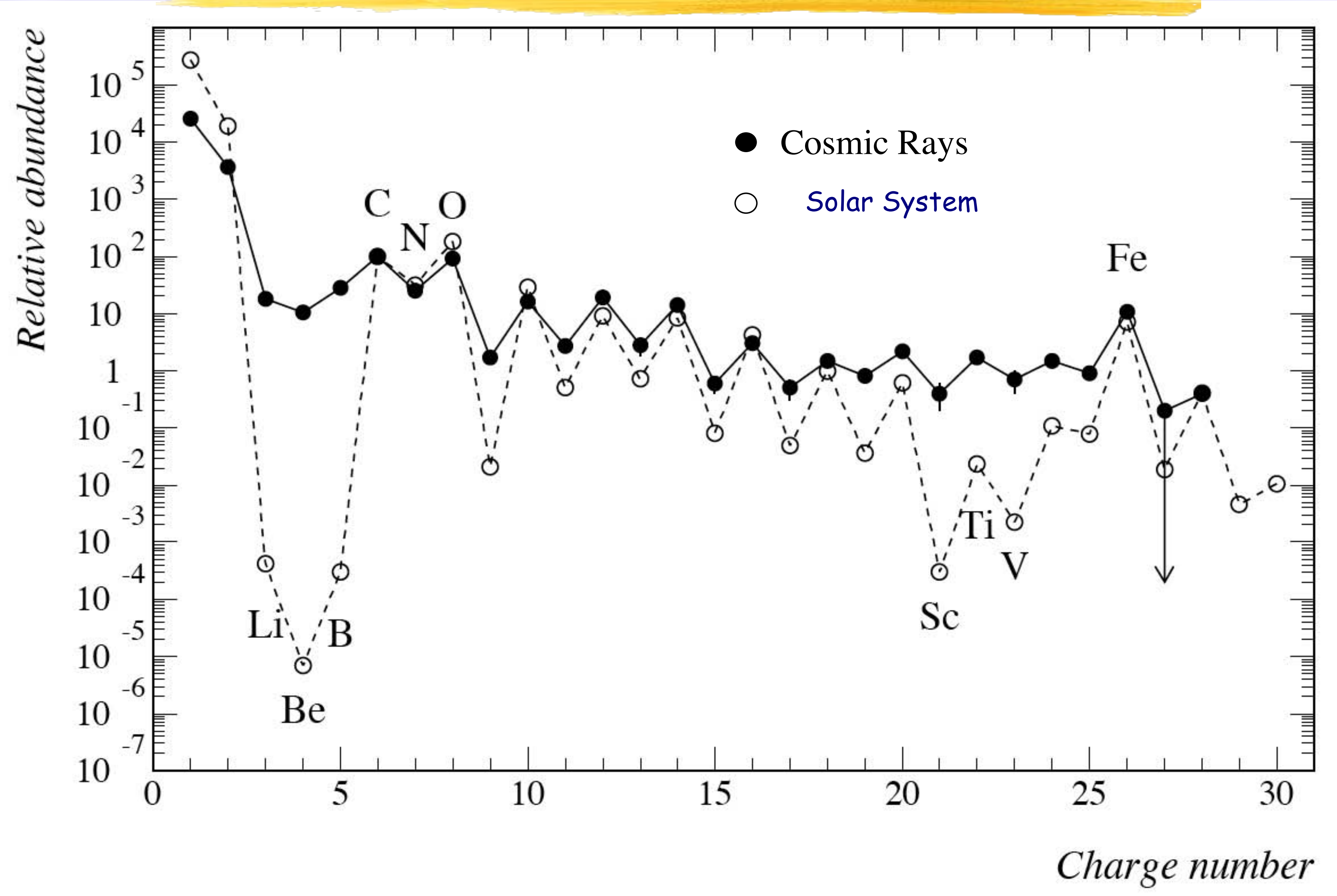
primary spectra injection index

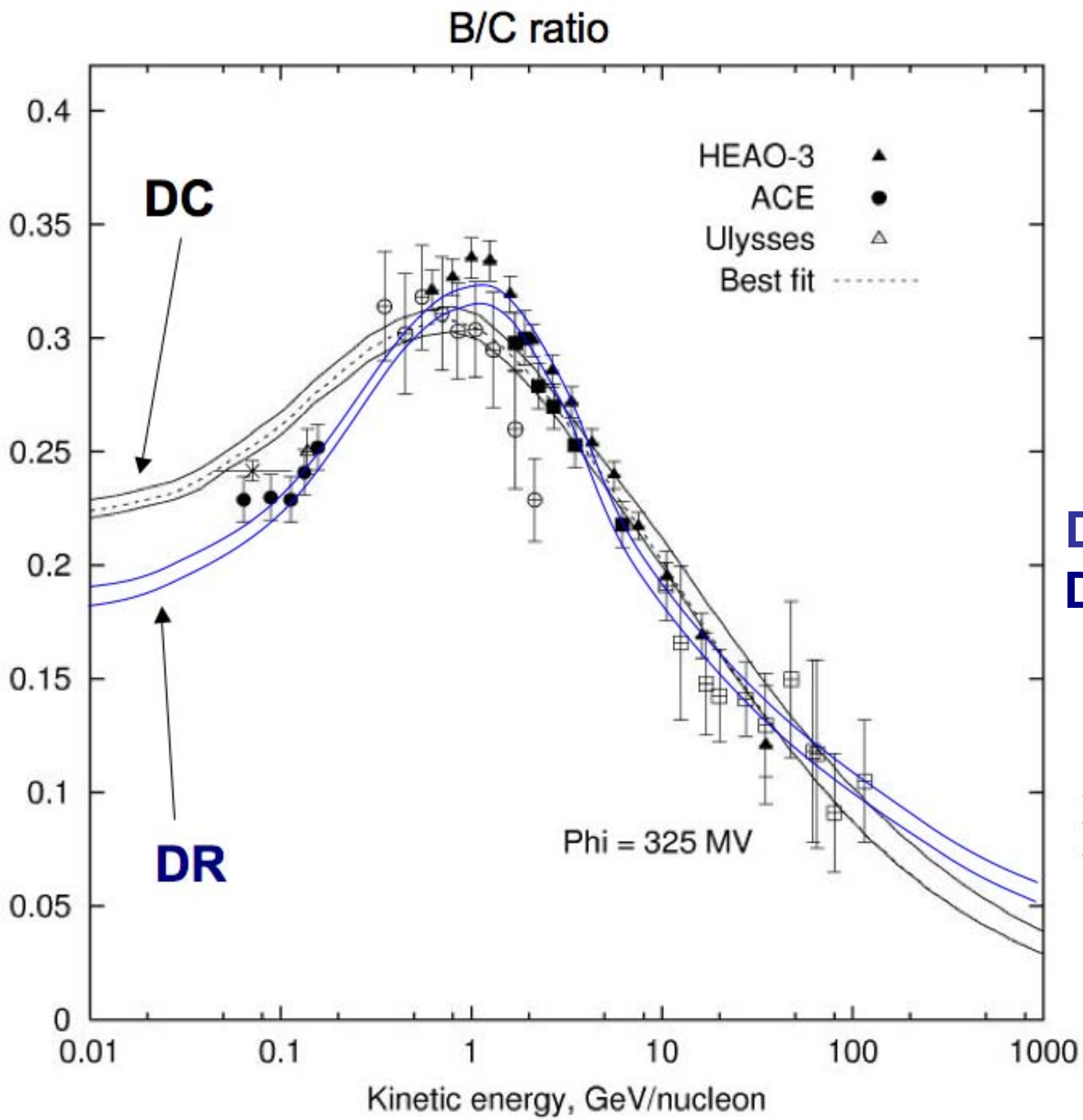
$$dq(p)/dp \propto p^{-\gamma}$$

implemented in Galprop (Strong & Moskalenko, available on the Web)

[astro-ph/0502406]

Comparison between the cosmic rays and the Solar System element composition, both relative to Carbon





Enveloping curves of all the good fits of the experimental B/C data

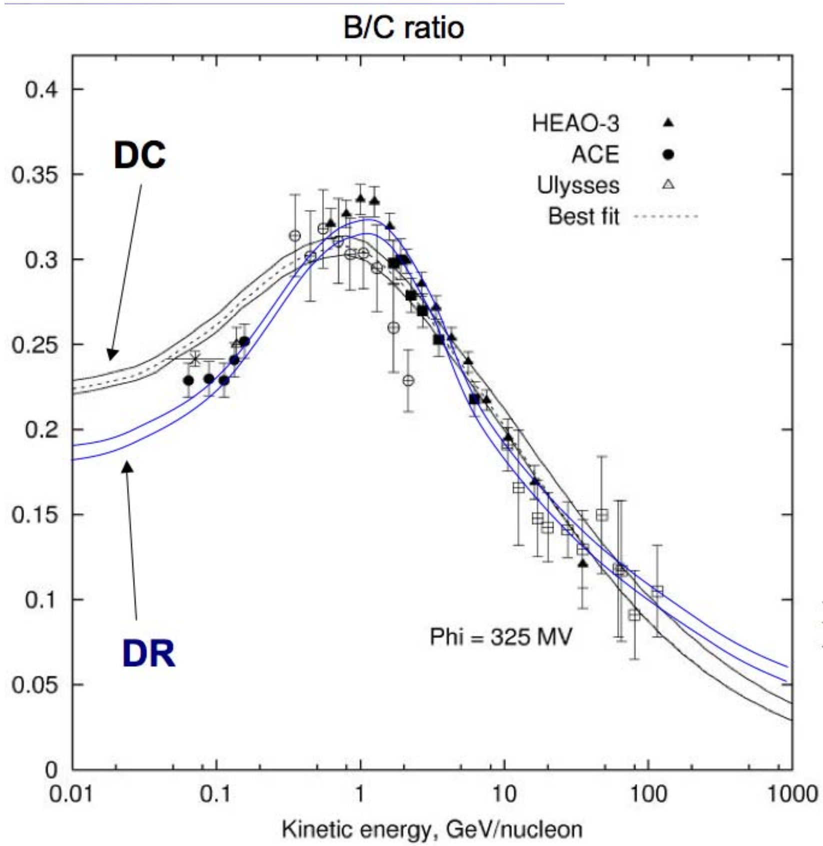
Dashed line: Best fit

DR: diffusion+ reacceleration

DC: diffusion+convection

In DC model problem with the ACE data at low energy

A.Lionetto, A.Morselli, V.Zdravkovic
JCAP09(2005)010 astro-ph/0502406



Enveloping curves of all the good fits of the experimental B/C data

Dashed line: Best fit

DR: diffusion+ reacceleration

DC: diffusion+convection

$$\chi^2 = \frac{1}{N-1}\sum_n \frac{1}{(\sigma_n^{B/C})^2}(\Phi_{n,exp}^{B/C} - \Phi_{n,teo}^{B/C})^2$$

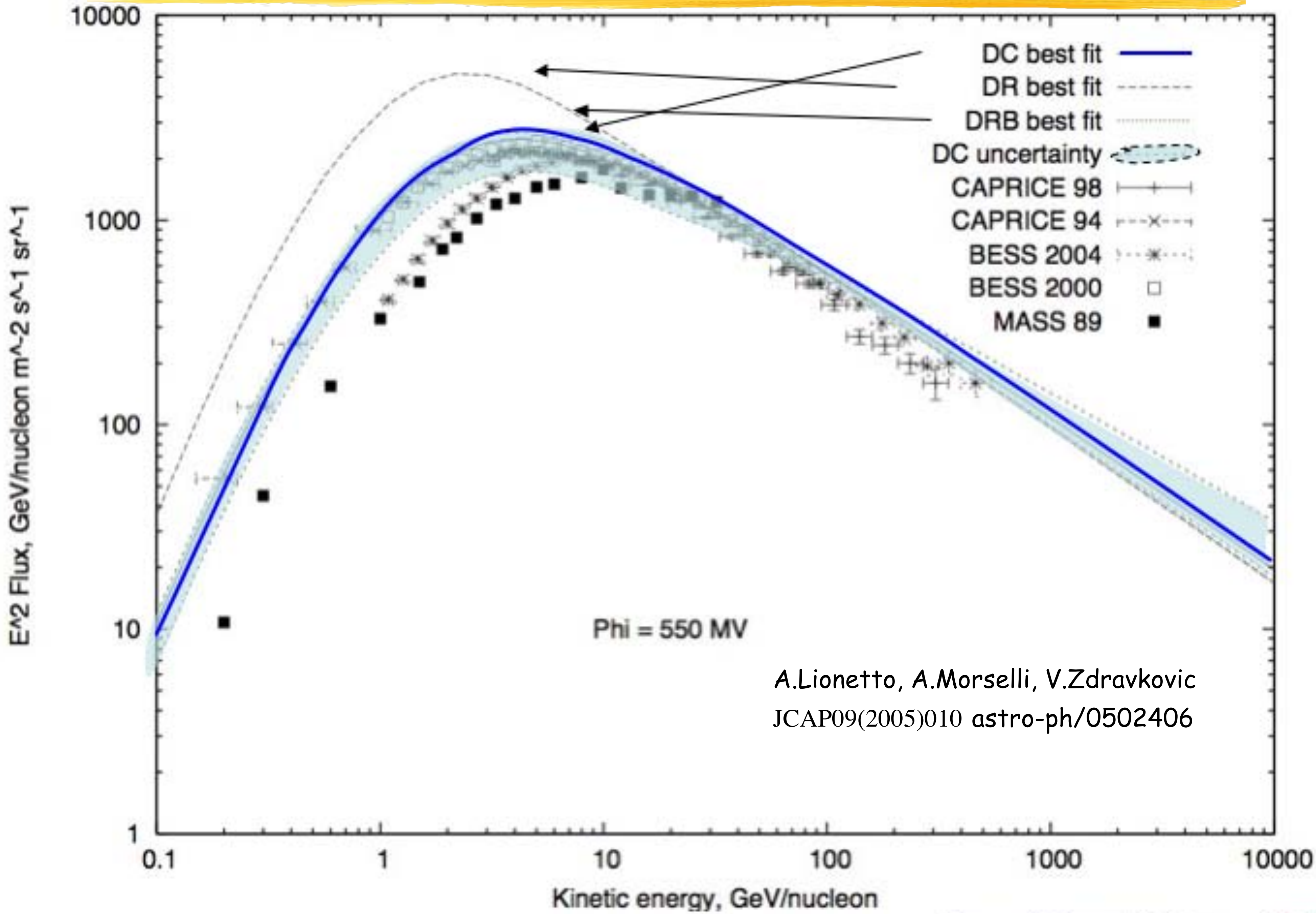
$\sigma_n^{B/C}$ = statistical errors for

N = 46 experimental points

A.Lionetto, A.Morselli, V.Zdravkovic

JCAP09(2005)010 astro-ph/0502406

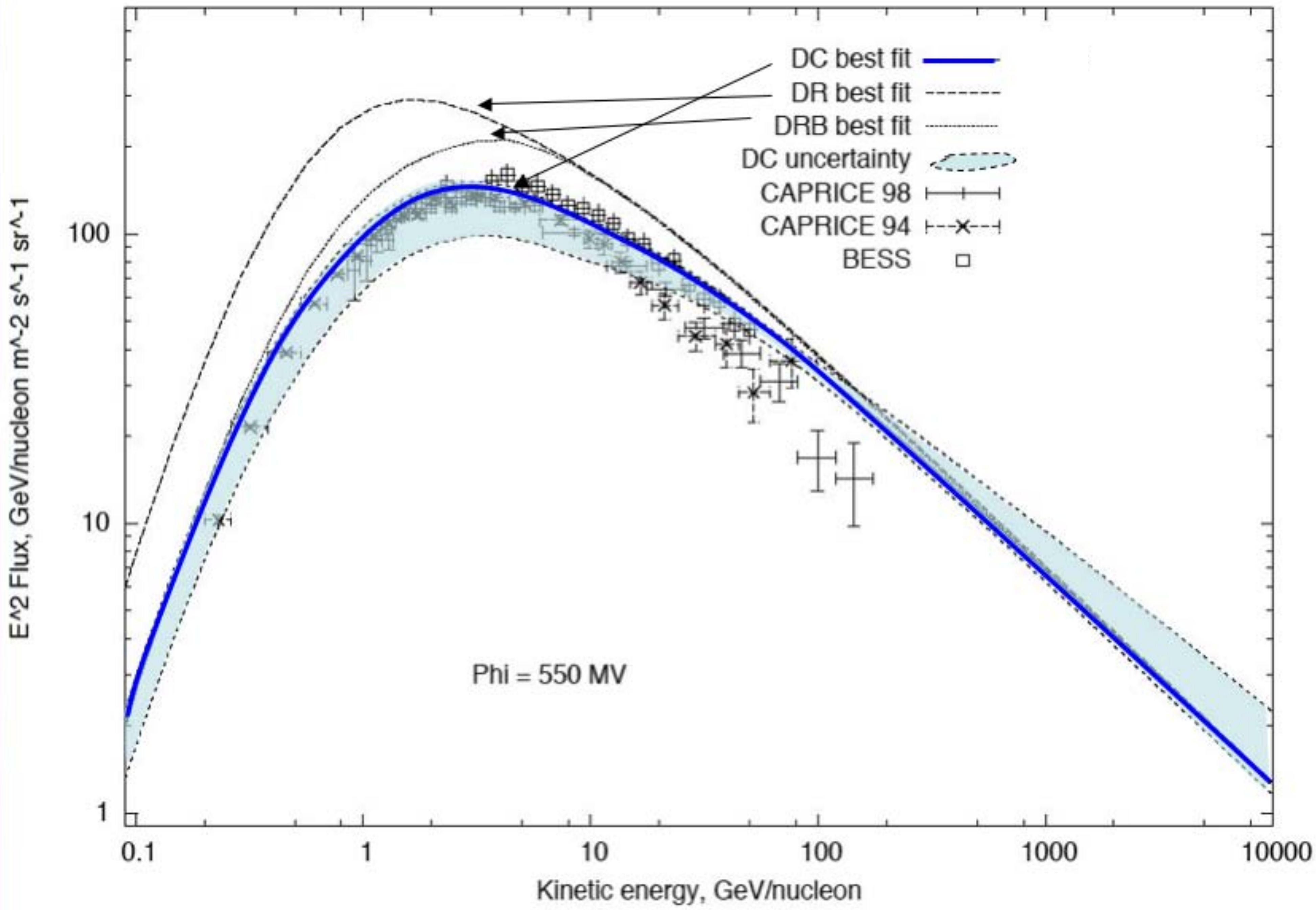
Proton spectra: Upper and lower bounds of due to the uncertainties of propagation parameters

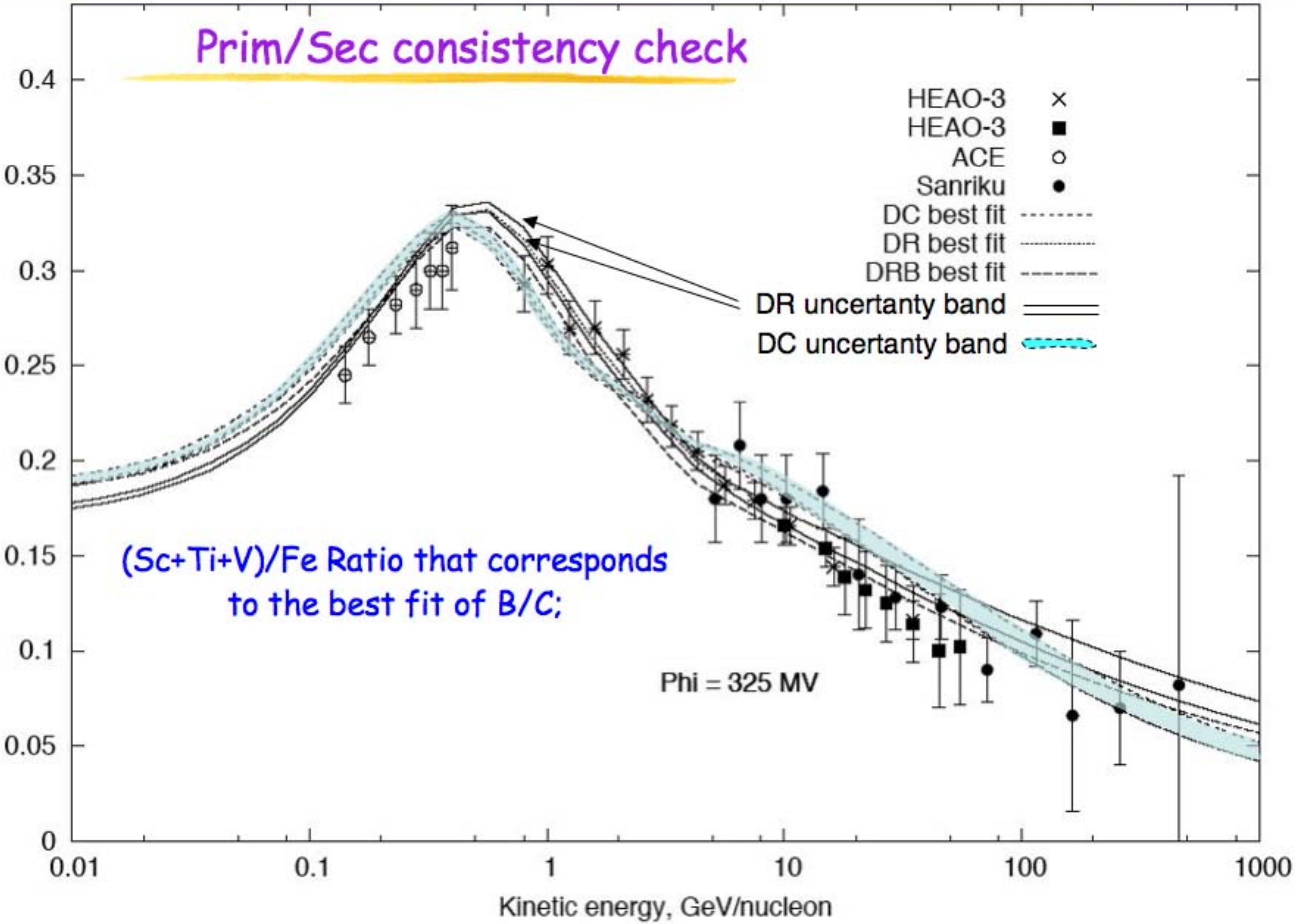


A.Lionetto, A.Morselli, V.Zdravkovic

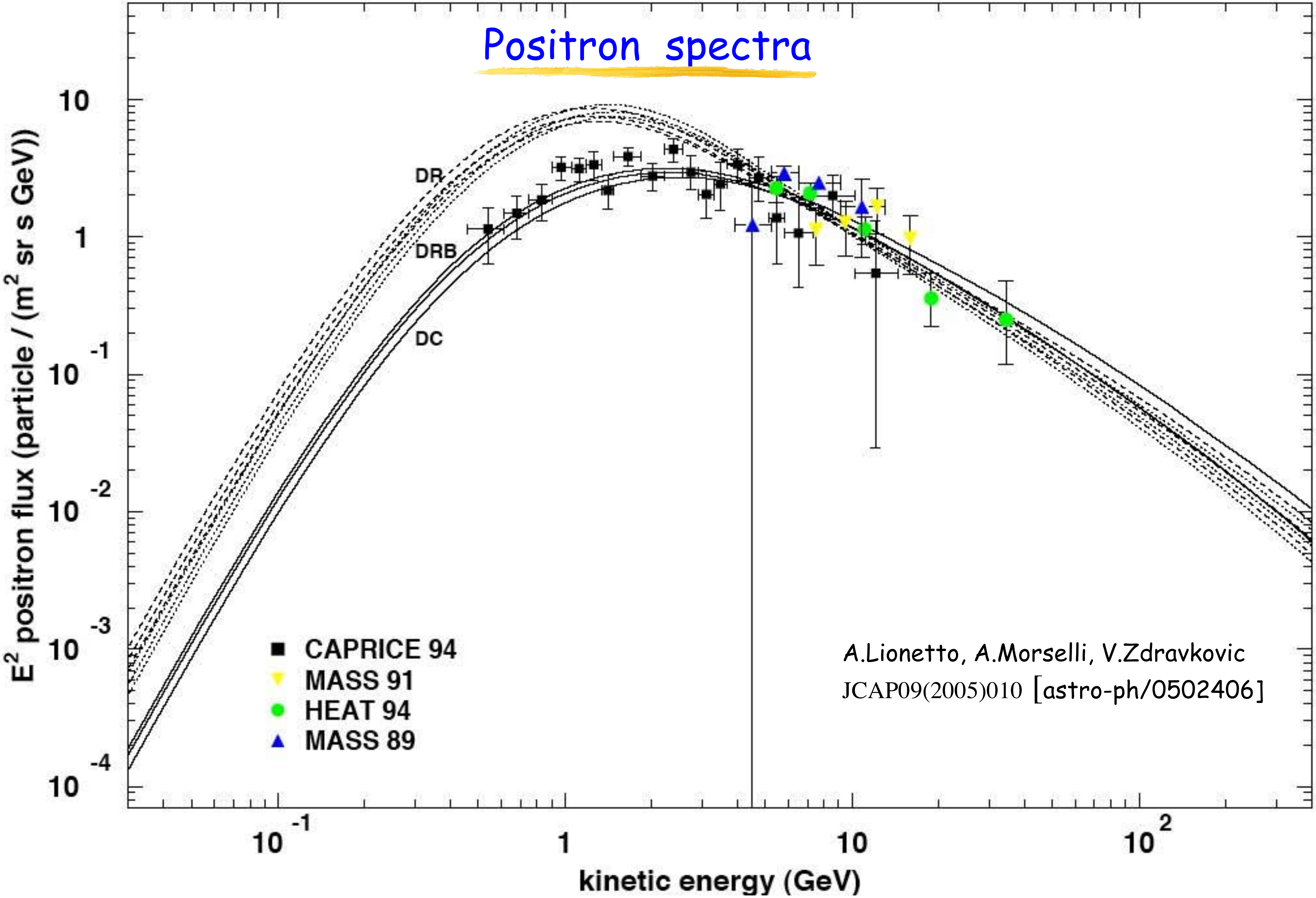
JCAP09(2005)010 astro-ph/0502406

Helium spectra: Upper and lower bounds of due to the uncertainties of propagation parameters

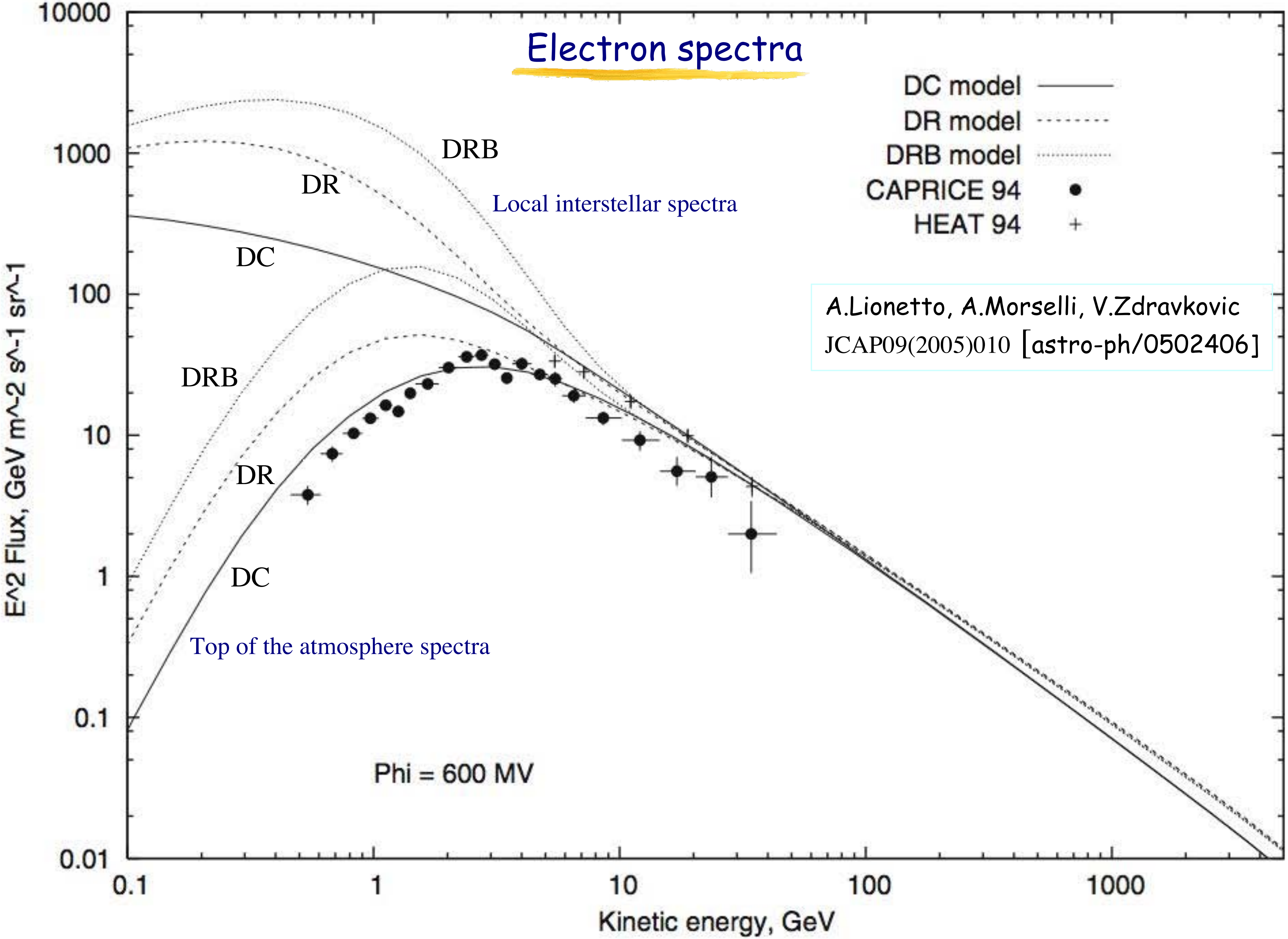



Prim/Sec consistency check
HEAO-3
HEAO-3
ACE
Sanriku
DC best fit
DR best fit
DRB best fit
DR uncertanty band
DC uncertanty band
(Sc+Ti+V)/Fe Ratio that corresponds
to the best fit of B/C;
Phi = 325 MV
Kinetic energy, GeV/nucleon
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.01
0.1
1
10
100
1000

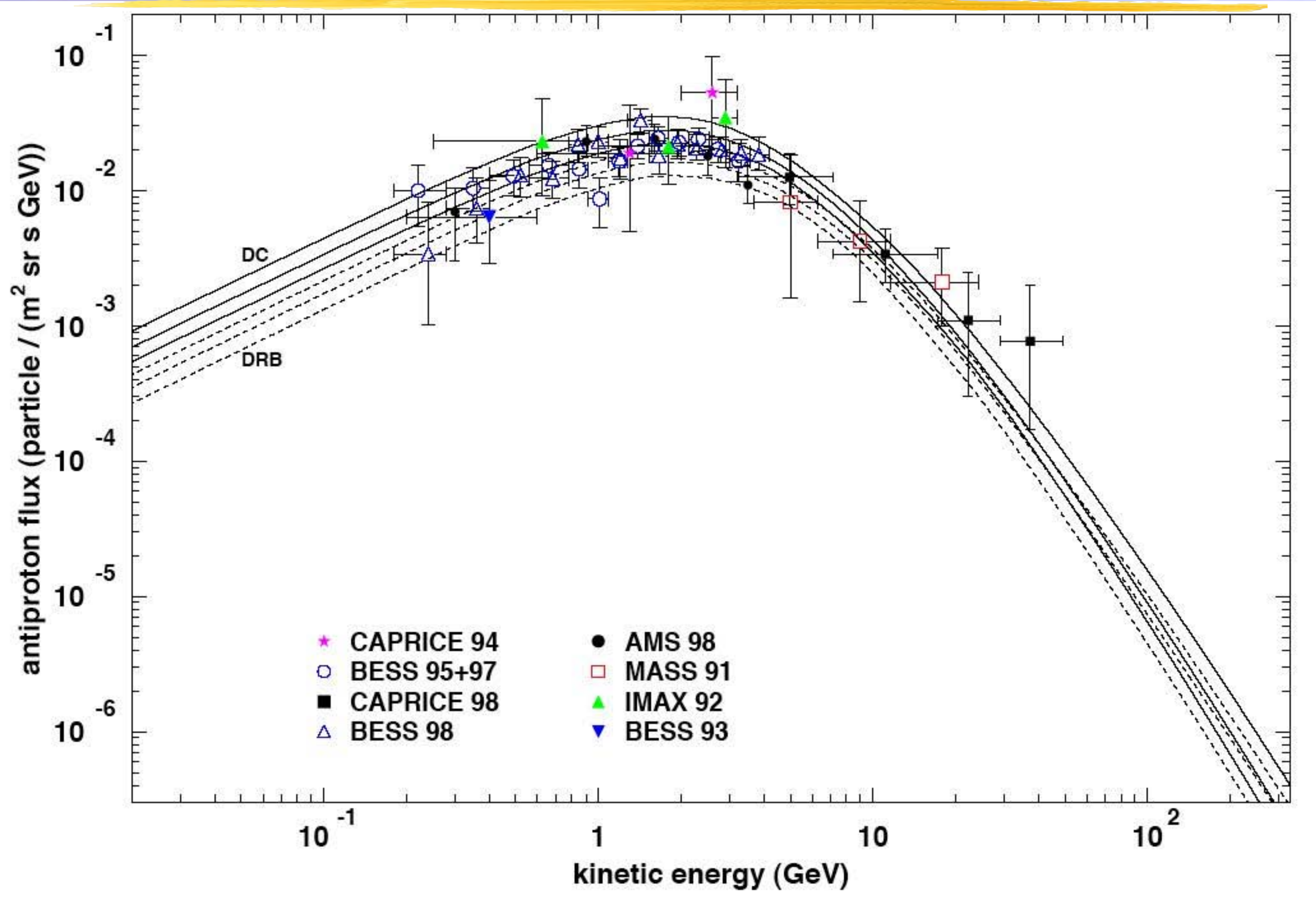
Positron spectra



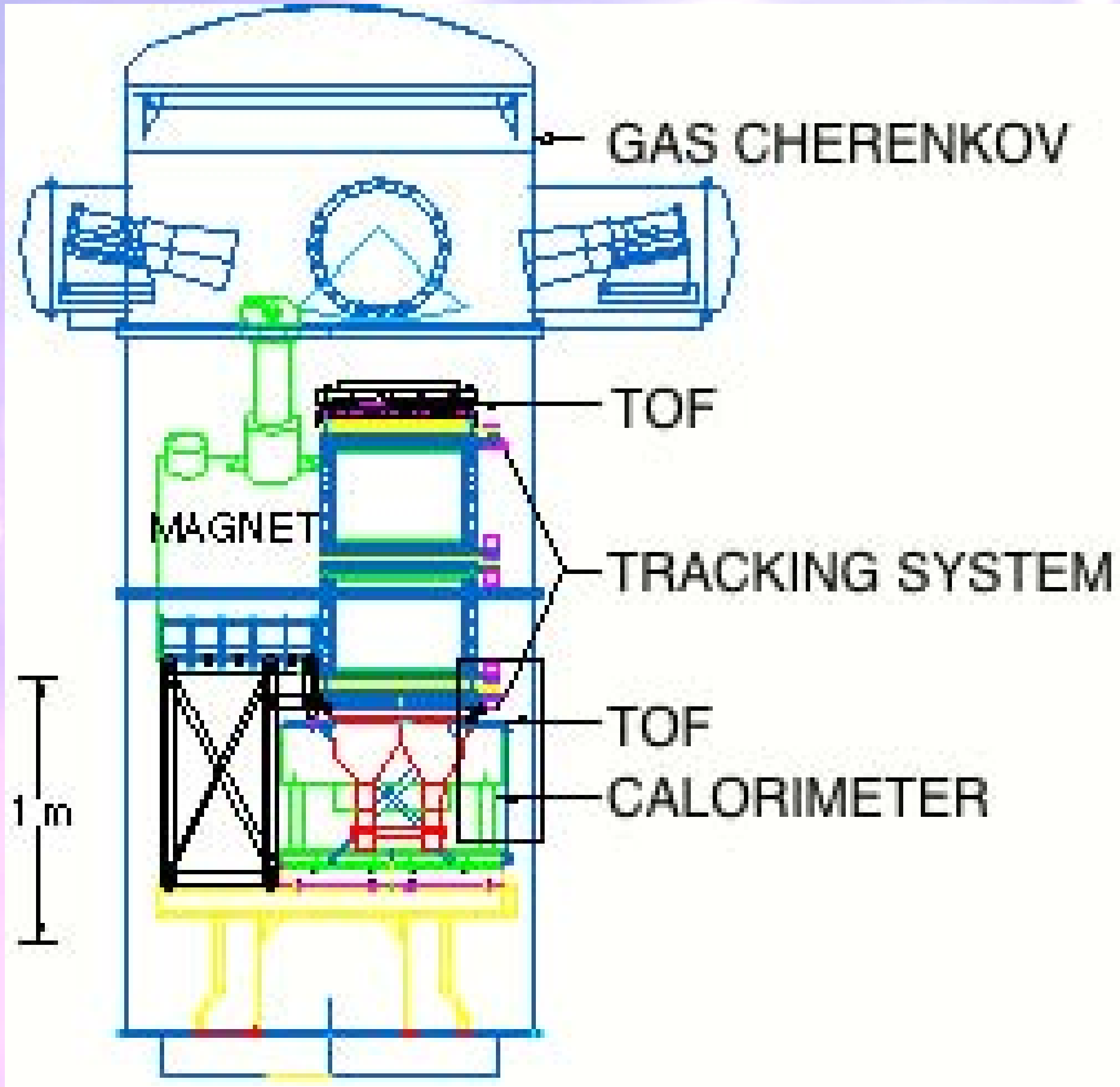
A.Lionetto, A.Morselli, V.Zdravkovic
JCAP09(2005)010 [astro-ph/0502406]


Electron spectra
DC model
DR model
DRB model
CAPRICE 94
HEAT 94
DRB
DR
DC
Local interstellar spectra
A.Lionetto, A.Morselli, V.Zdravkovic
JCAP09(2005)010 [astro-ph/0502406]
DRB
DR
DC
Top of the atmosphere spectra
Phi = 600 MV
E^2 Flux, GeV m^-2 s^-1 sr^-1
Kinetic energy, GeV
10000
1000
100
10
1
0.1
0.01
0.1
1
10
100
1000

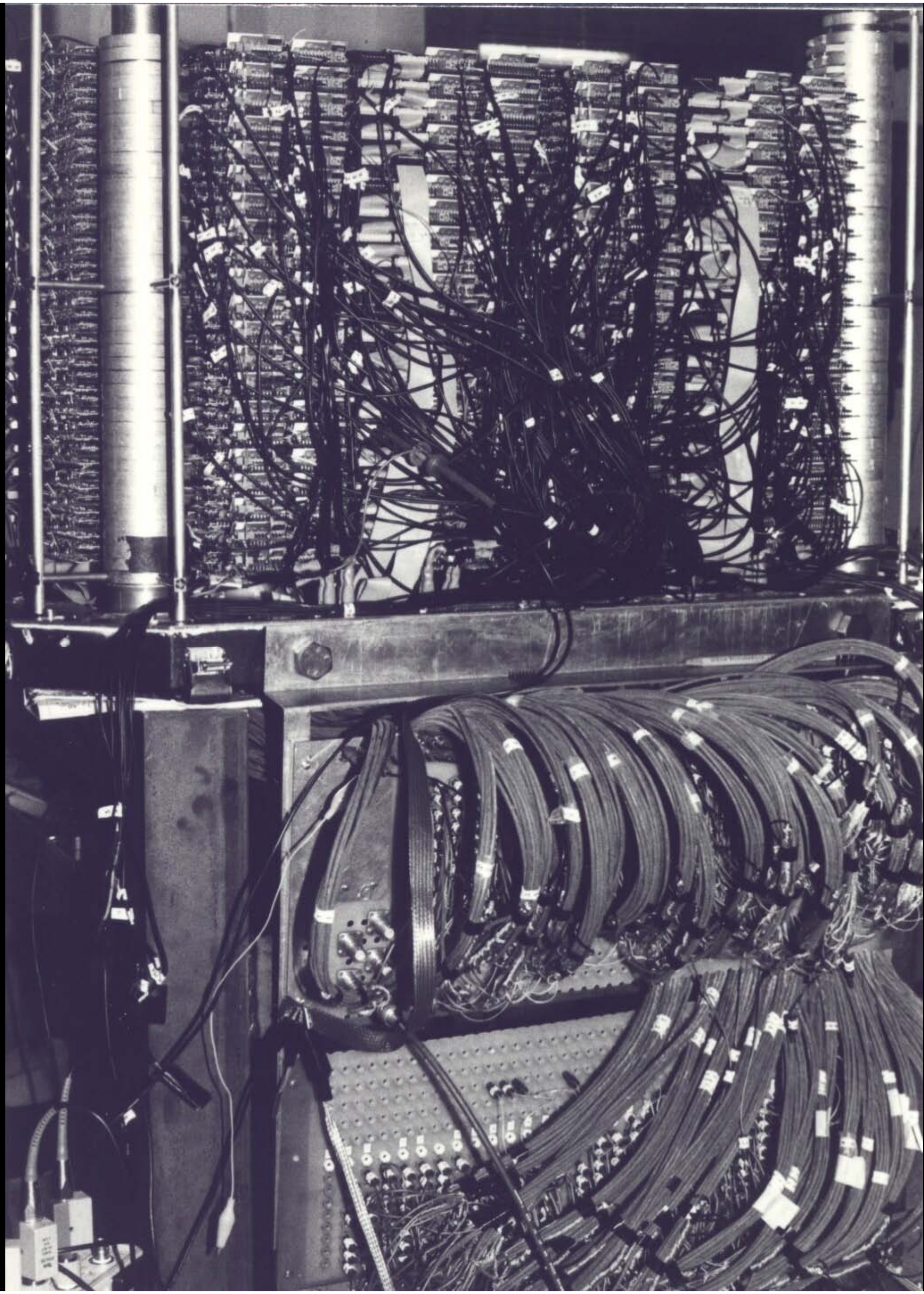
Antiproton spectra: Upper and lower bounds of due to the uncertainties of propagation parameters



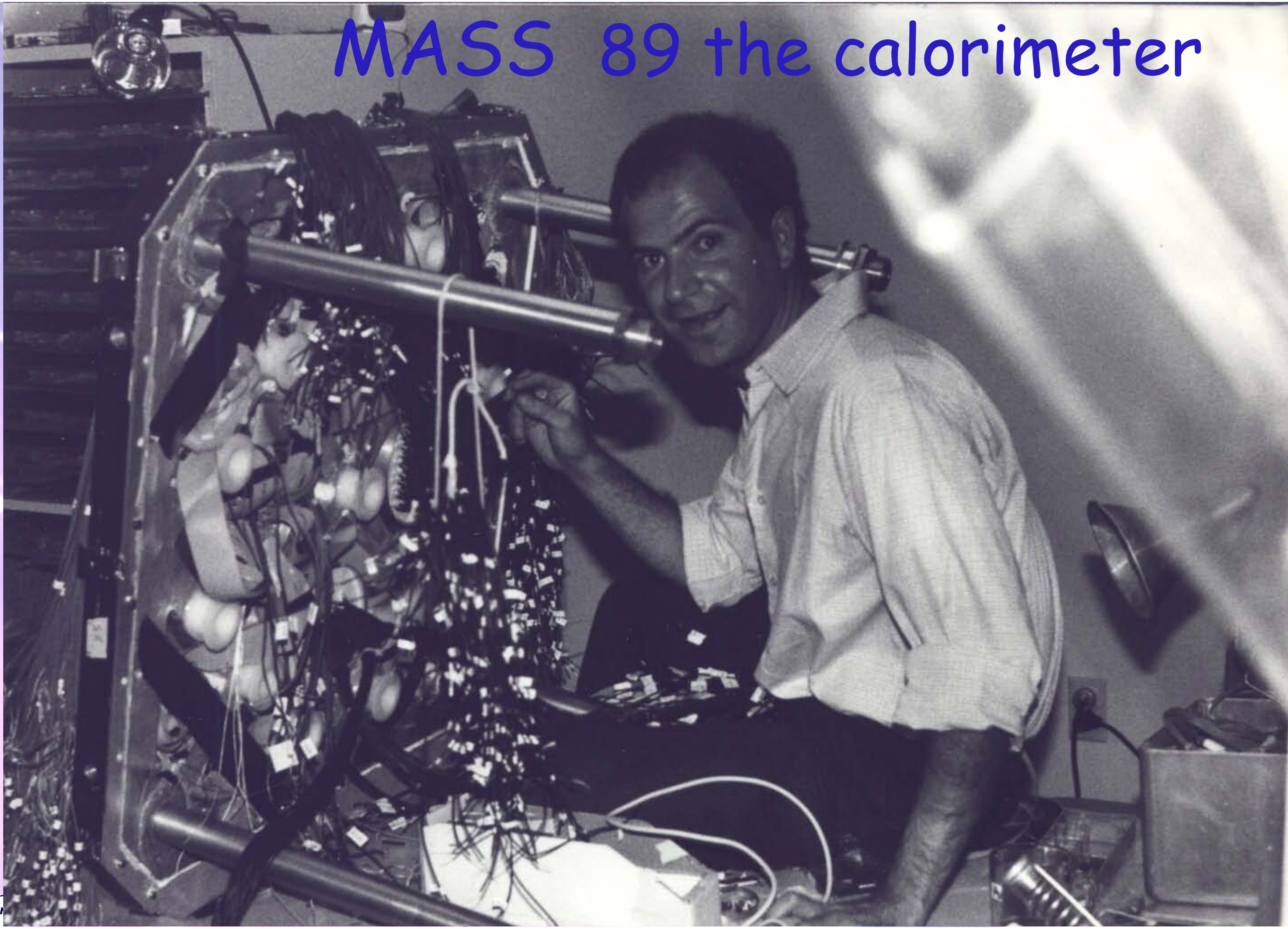
MASS Matter Antimatter Space Spectrometer



the MASS89 Calorimeter



MASS 89 the calorimeter



from Las Cruces to Prince Albert


HOLD


MASS 89 flight


MASS 89 flight


MASS 89

PAMELA

Payload for **A**ntimatter **M**atter **E**xploration and **L**ight Nuclei **A**strophysics

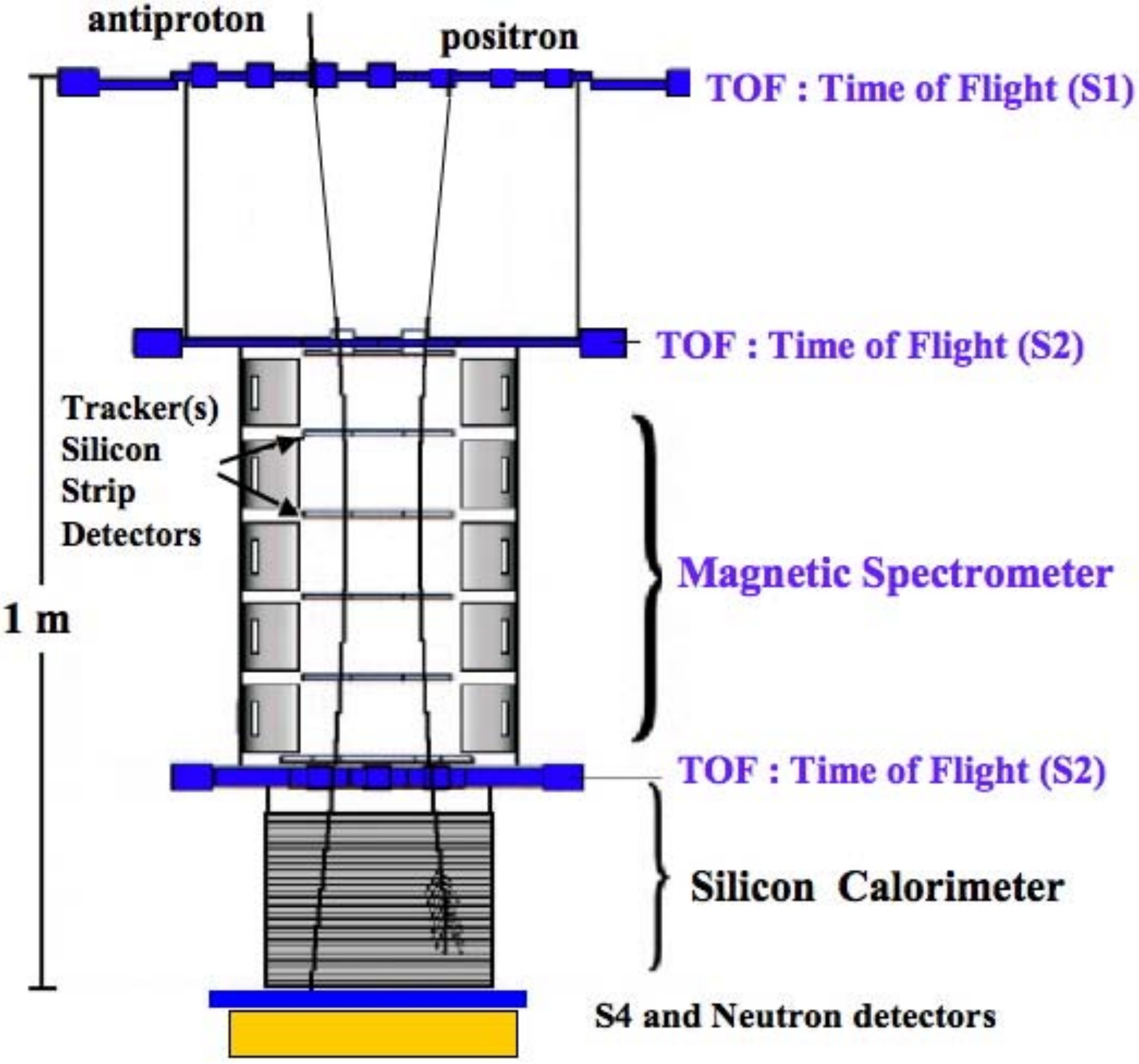
In orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour launch site.

First switch-on on June 21 2006

From July 11 Pamela is in continuous data taking mode

Pamela

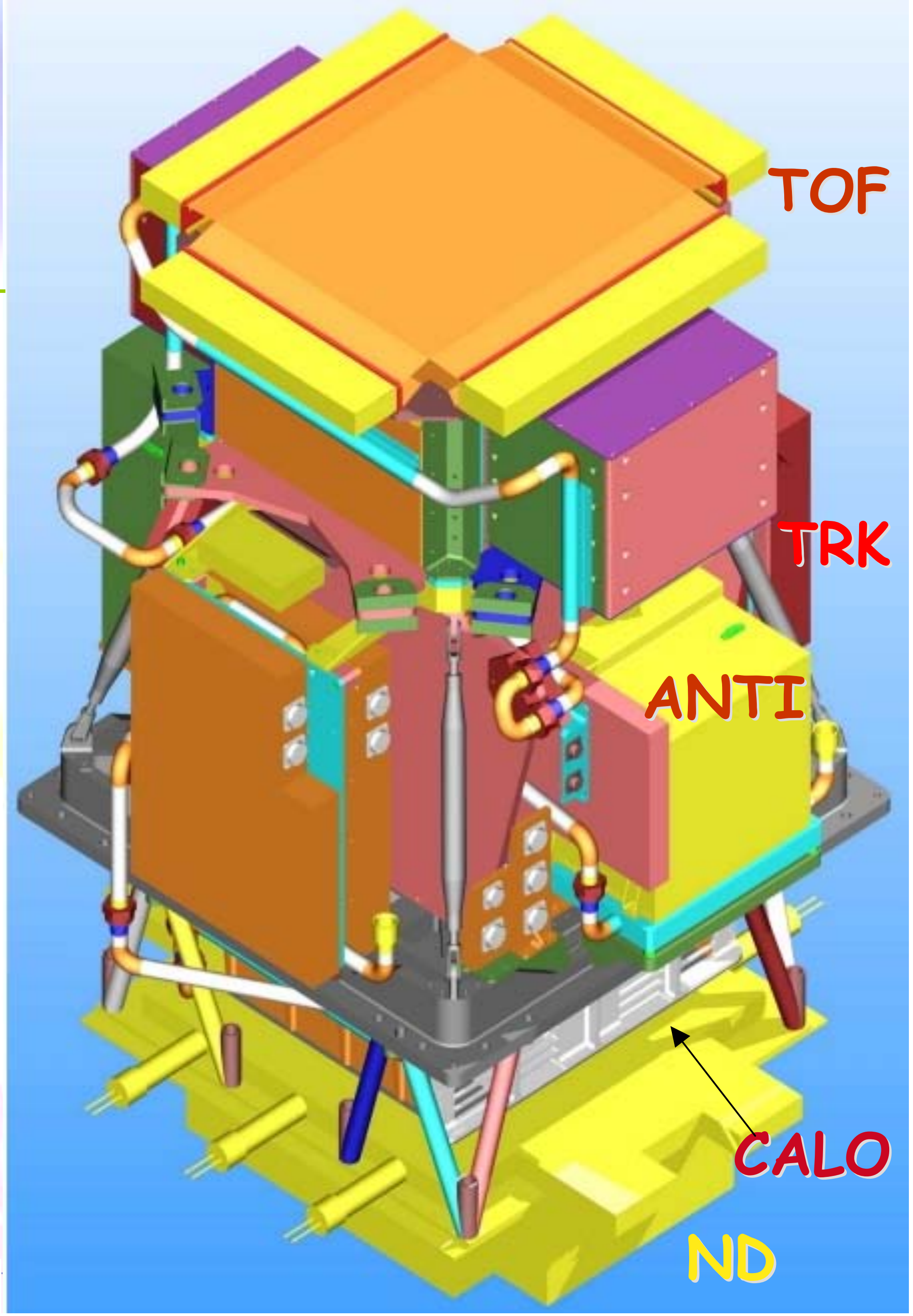
Separating p from e$^-$



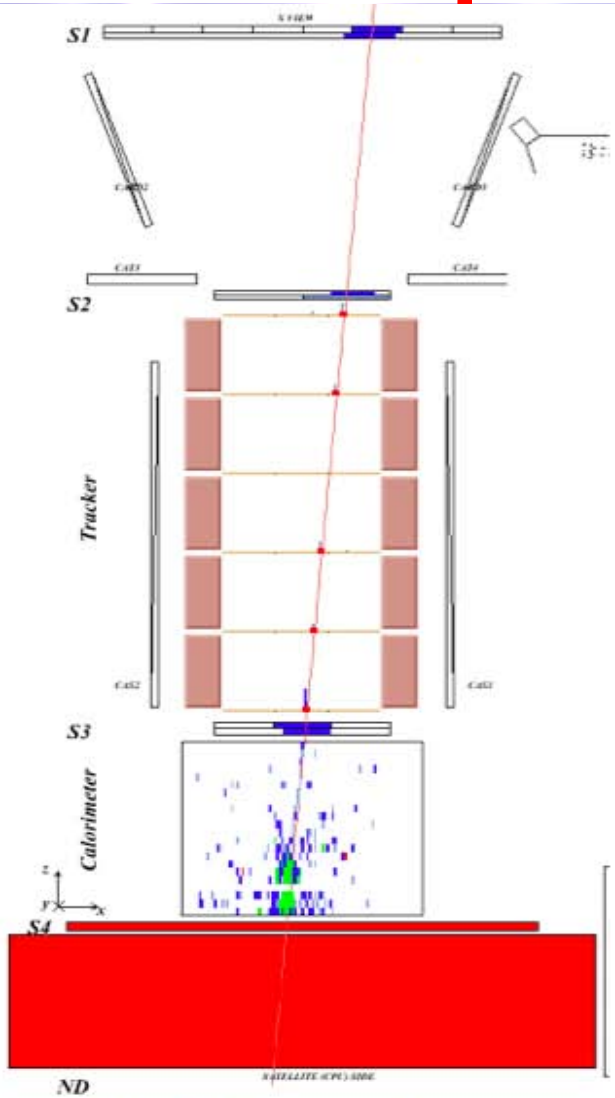
Pamela

- Protoni 80 MeV – 700 GeV
- Antiprotoni 80 MeV –190 GeV
- Elettroni 50 MeV – 2 TeV
- Positroni 50 MeV - 270 GeV
- Nuclei < 700 GeV/n
- Limite per Antinuclei 10^{-8}

- Massa del rivelatore 440 Kg
- Potenza 355 W
- MDR – 770 GV



Antiparticle identification



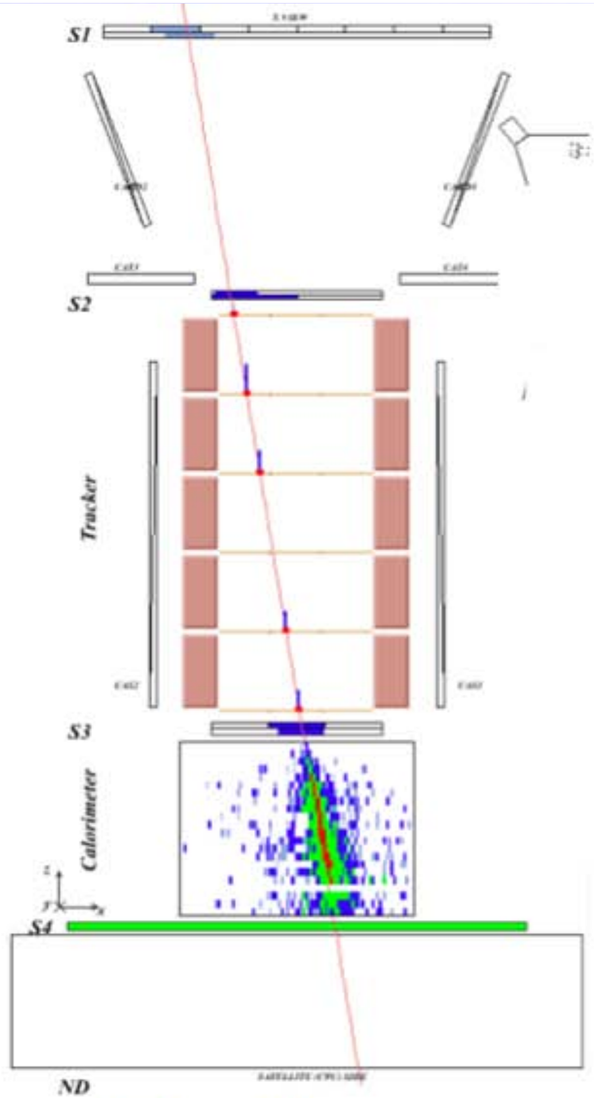
Antiproton
(NB: $e^-/\bar{p} \sim 10^2$)

Time-of-flight: trigger, albedo rejection, mass determination (up to 1 GeV)

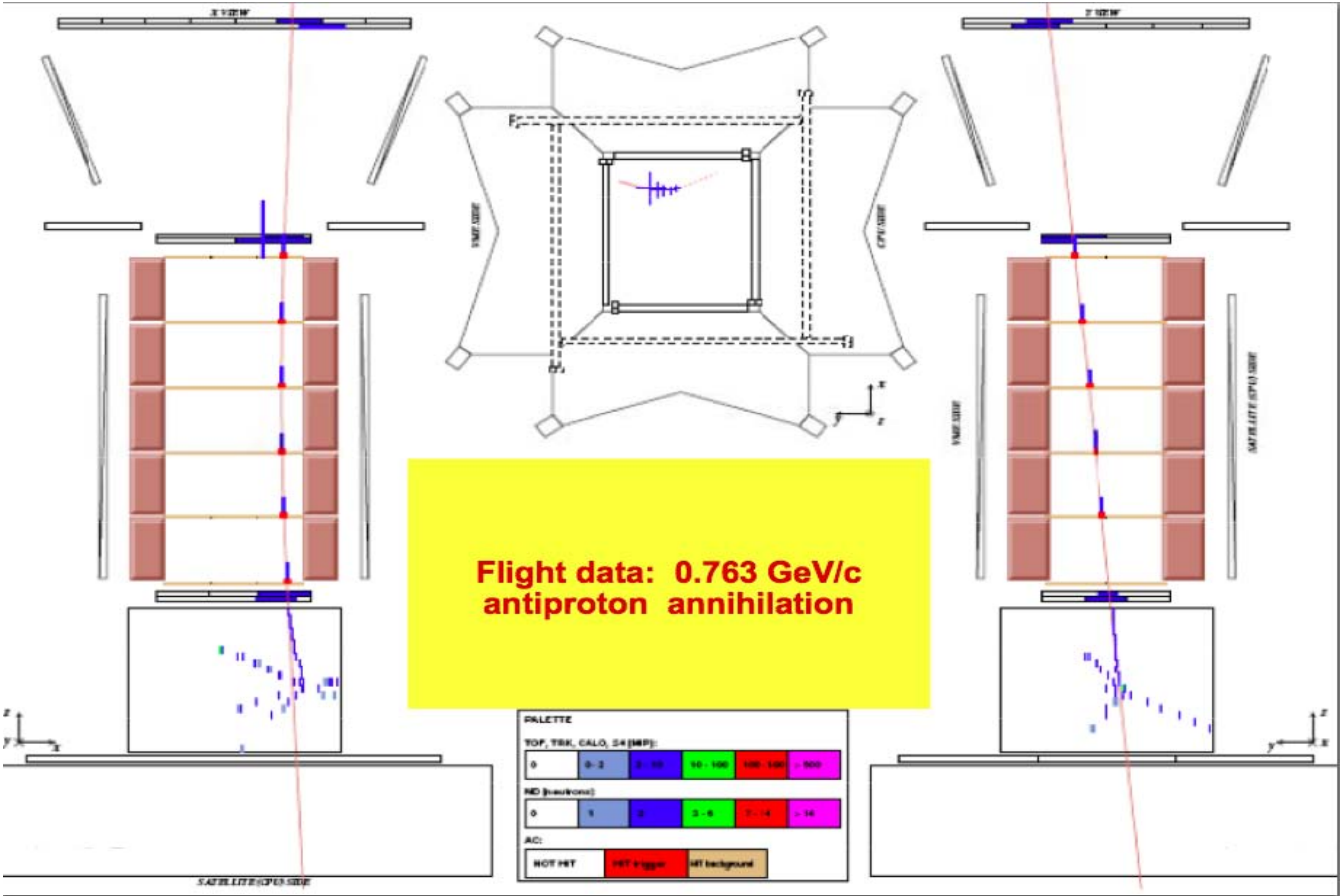
Bending in spectrometer: sign of charge

Ionisation energy loss (dE/dx): magnitude of charge

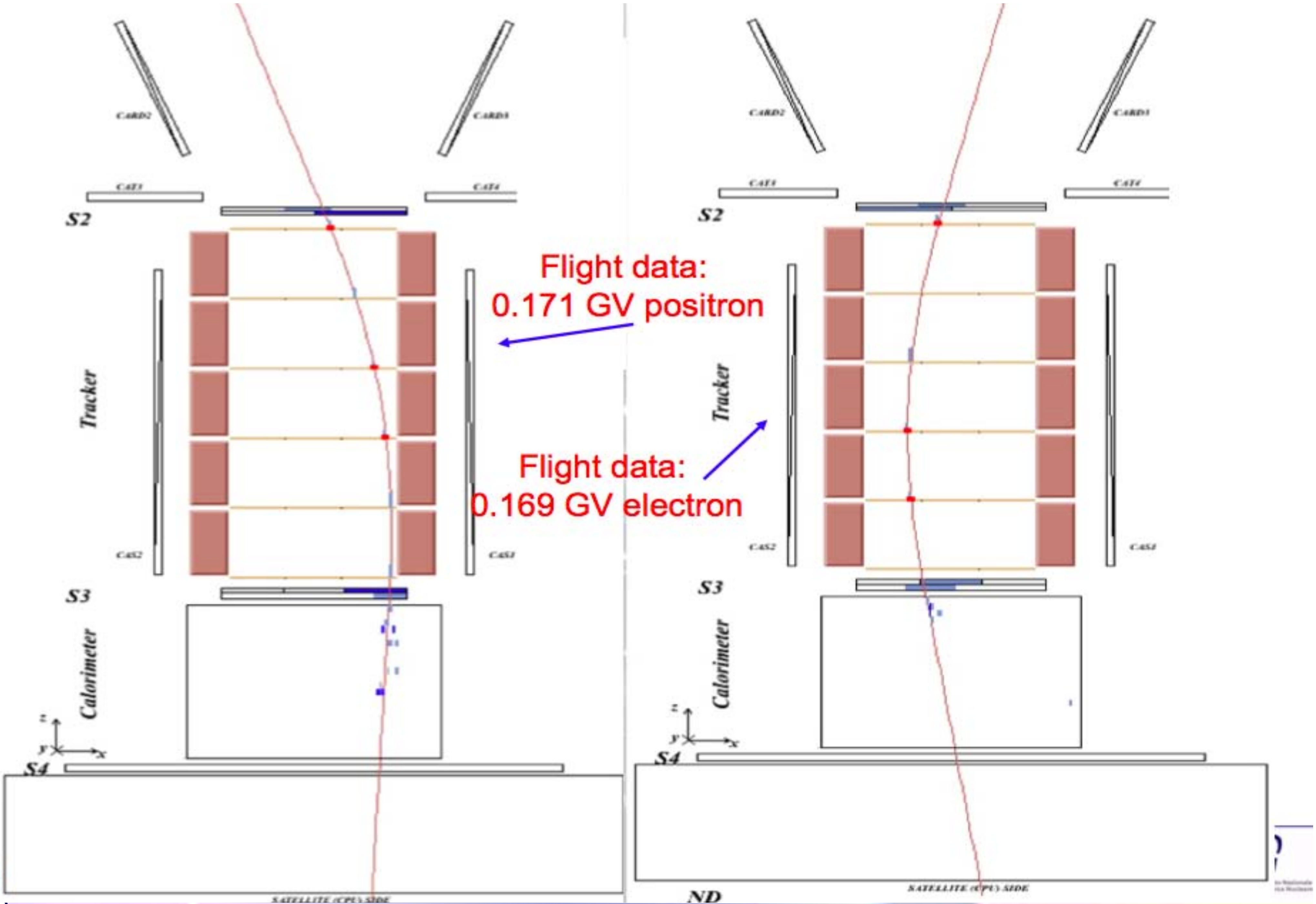
Interaction pattern in calorimeter: electron-like or proton-like, electron energy

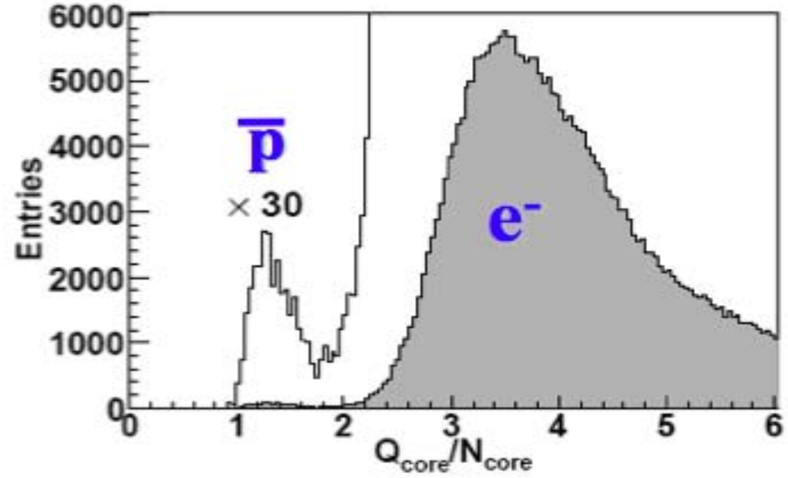


Positron
(NB: $p/e^+ \sim 10^{3-4}$)

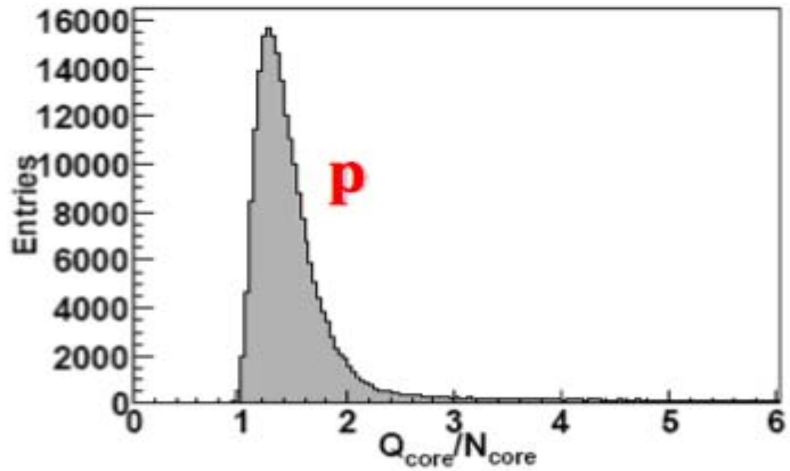


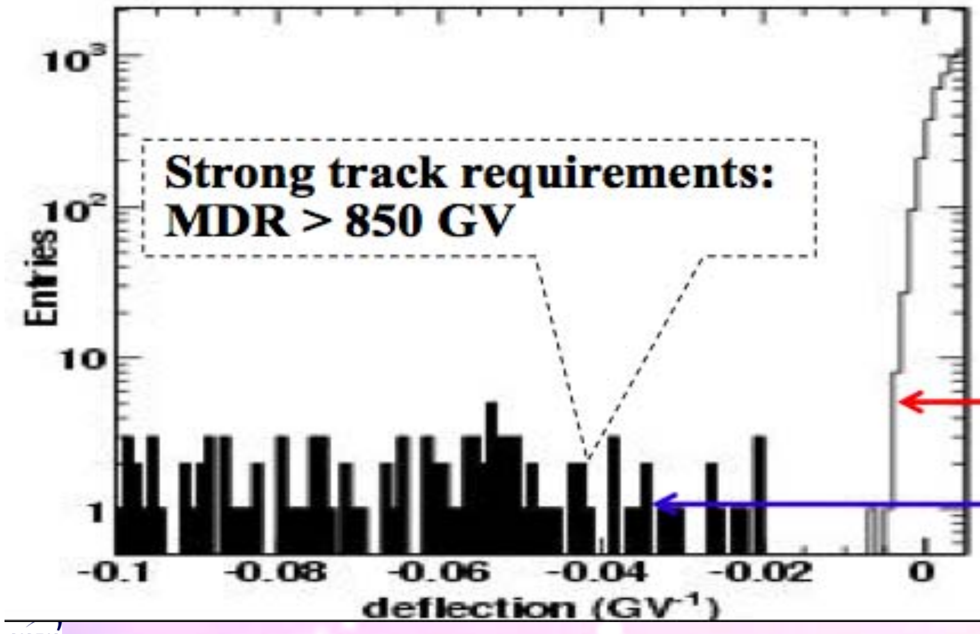
Flight data: 0.763 GeV/c antiproton annihilation


Flight data:
0.171 GV positron
Flight data:
0.169 GV electron
S2
S3
S4
Tracker
Calorimeter
ND



Calorimeter selection





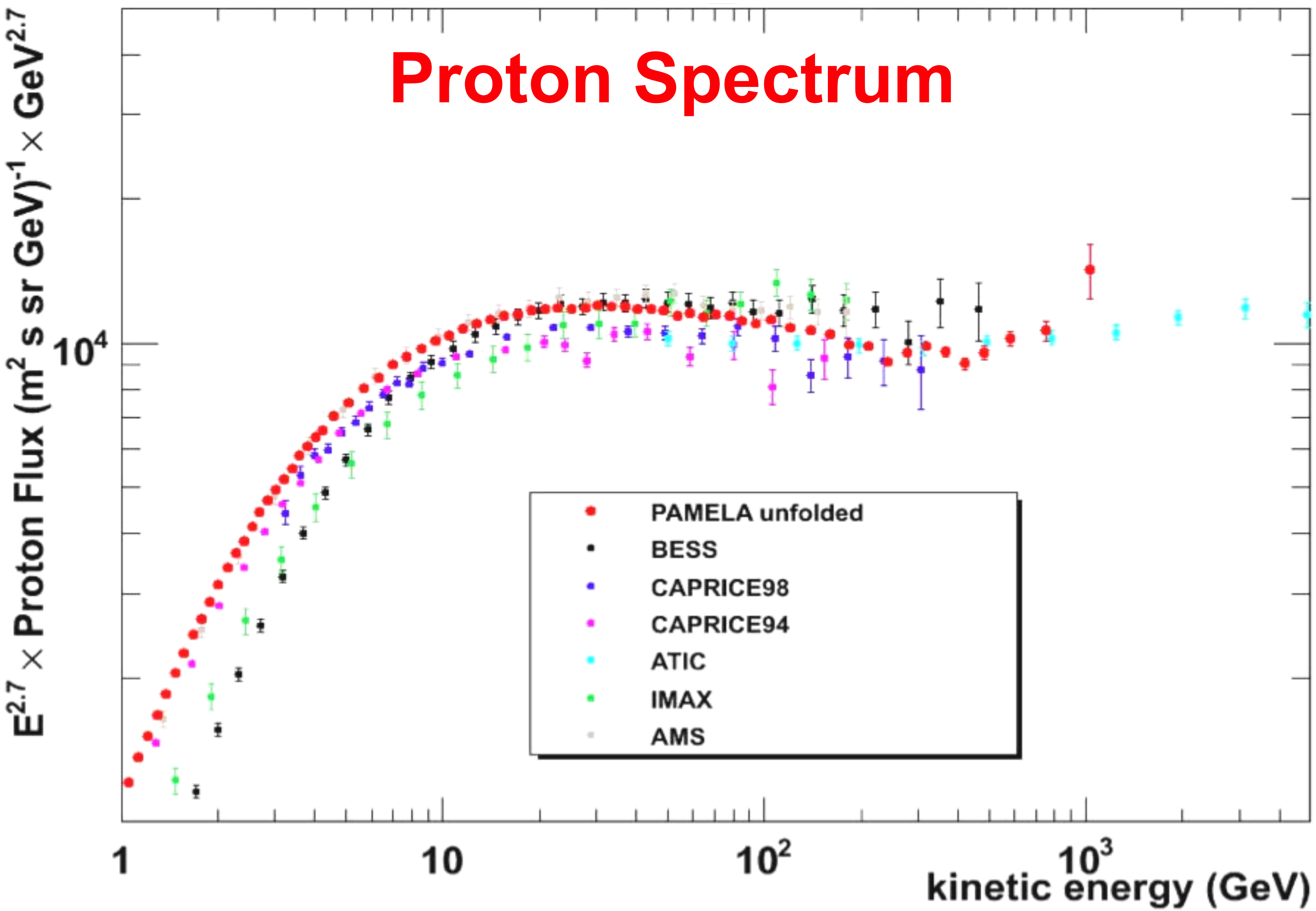
Tracker Identification

Protons (& spillover)

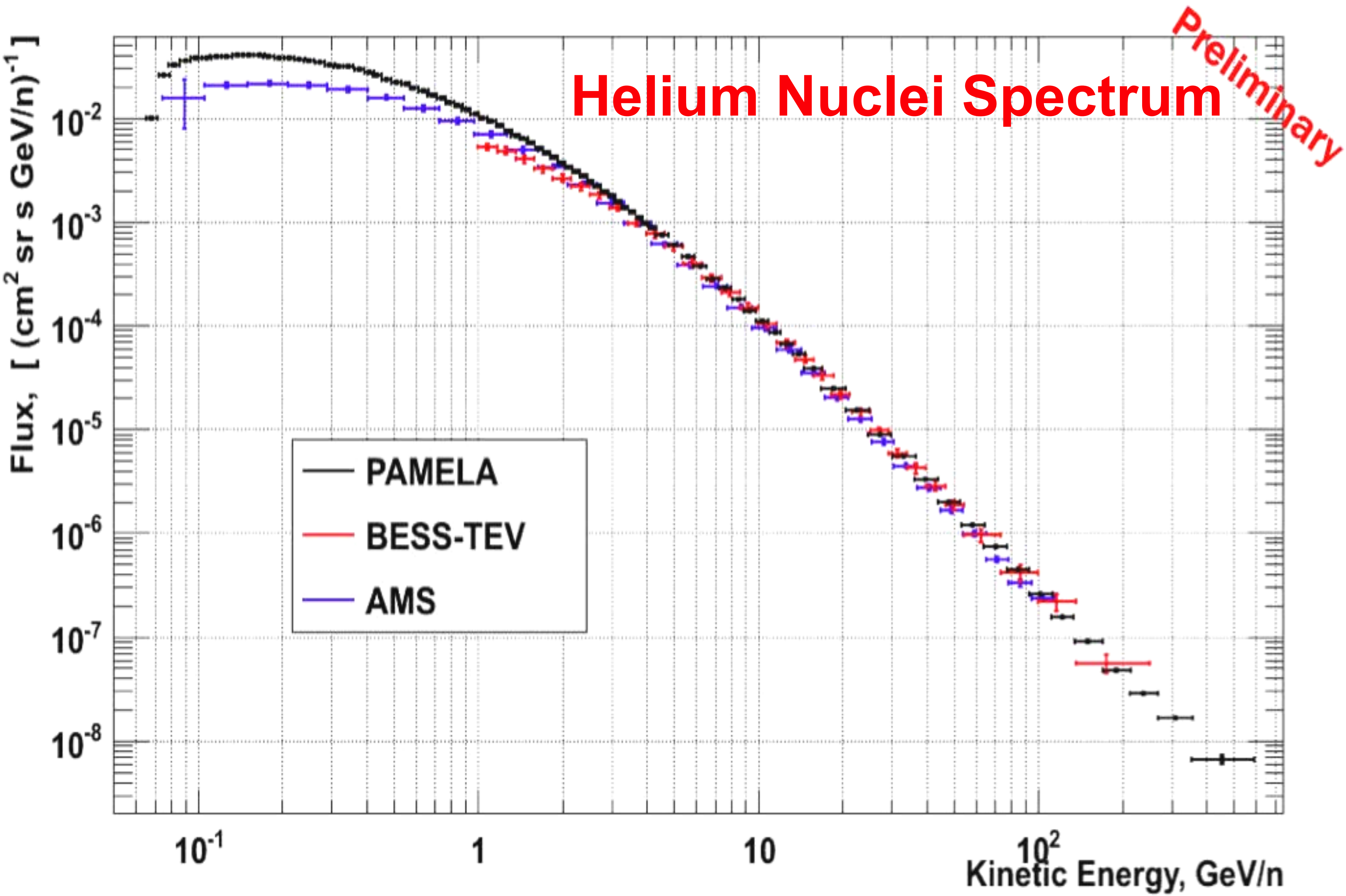
Antiprotons

- ~ 4 years from PAMELA launch

- Launched in orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour cosmodrom.

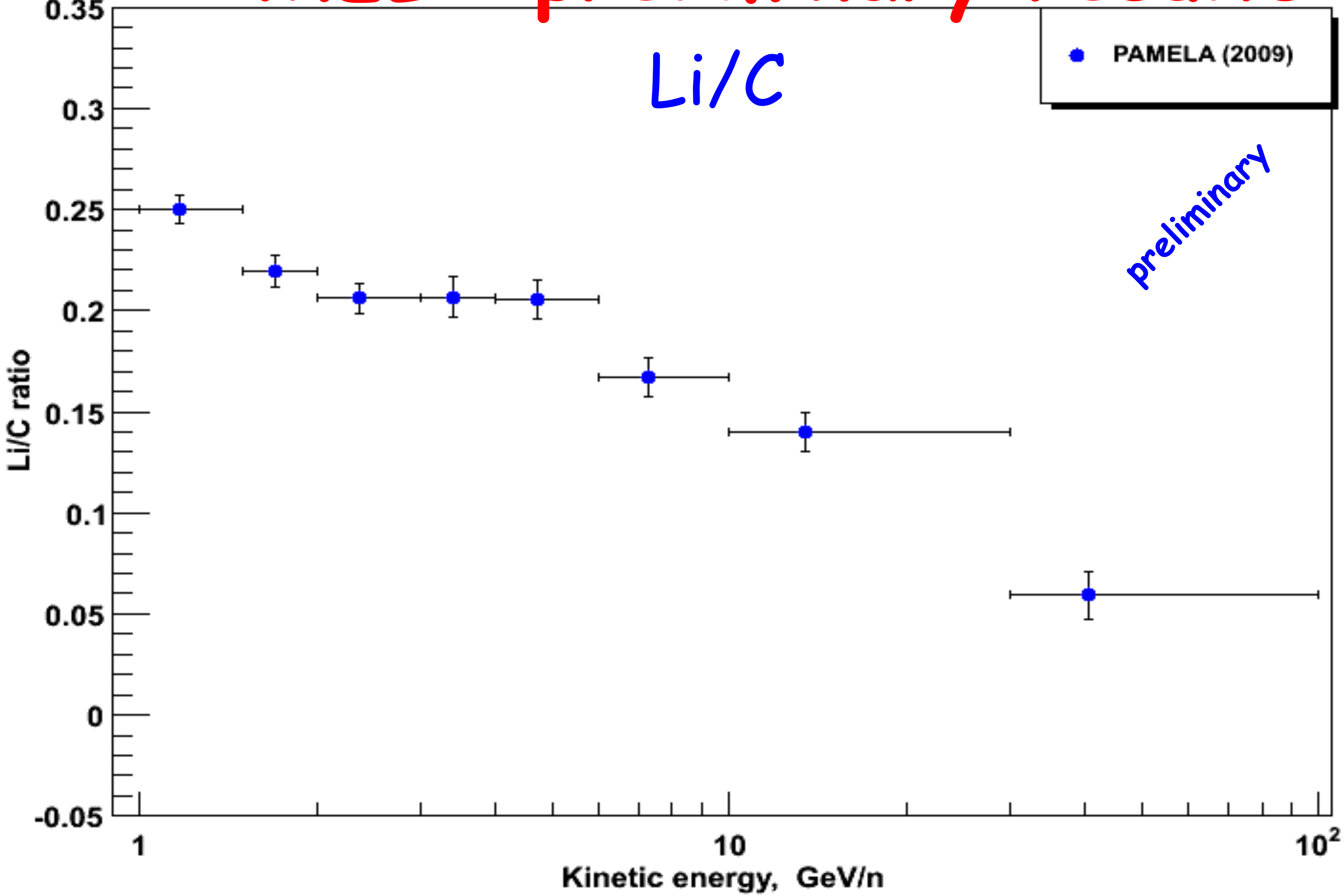


Proton Spectrum
PAMELA unfolded
BESS
CAPRICE98
CAPRICE94
ATIC
IMAX
AMS
$E^{2.7} \times$ Proton Flux $(m^2\ s\ sr\ GeV)^{-1} \times GeV^{2.7}$
10^4
1
10
10^2
10^3
kinetic energy (GeV)

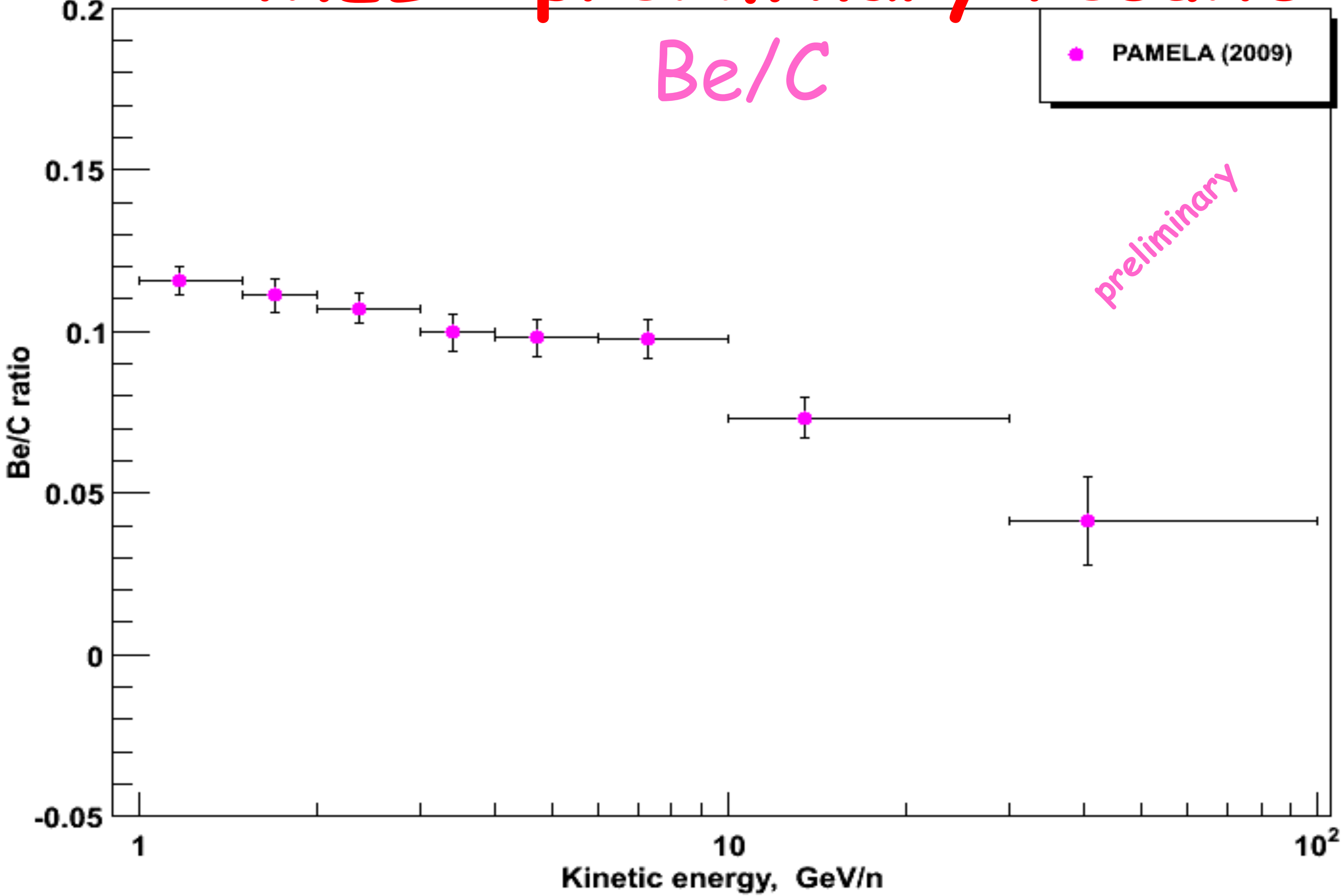


Helium Nuclei Spectrum
Preliminary
Flux, [(cm^2 sr s GeV/n)$^{-1}$]
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
PAMELA
BESS-TEV
AMS
10^{-1}
1
10
10^2
Kinetic Energy, GeV/n

PAMELA preliminary results

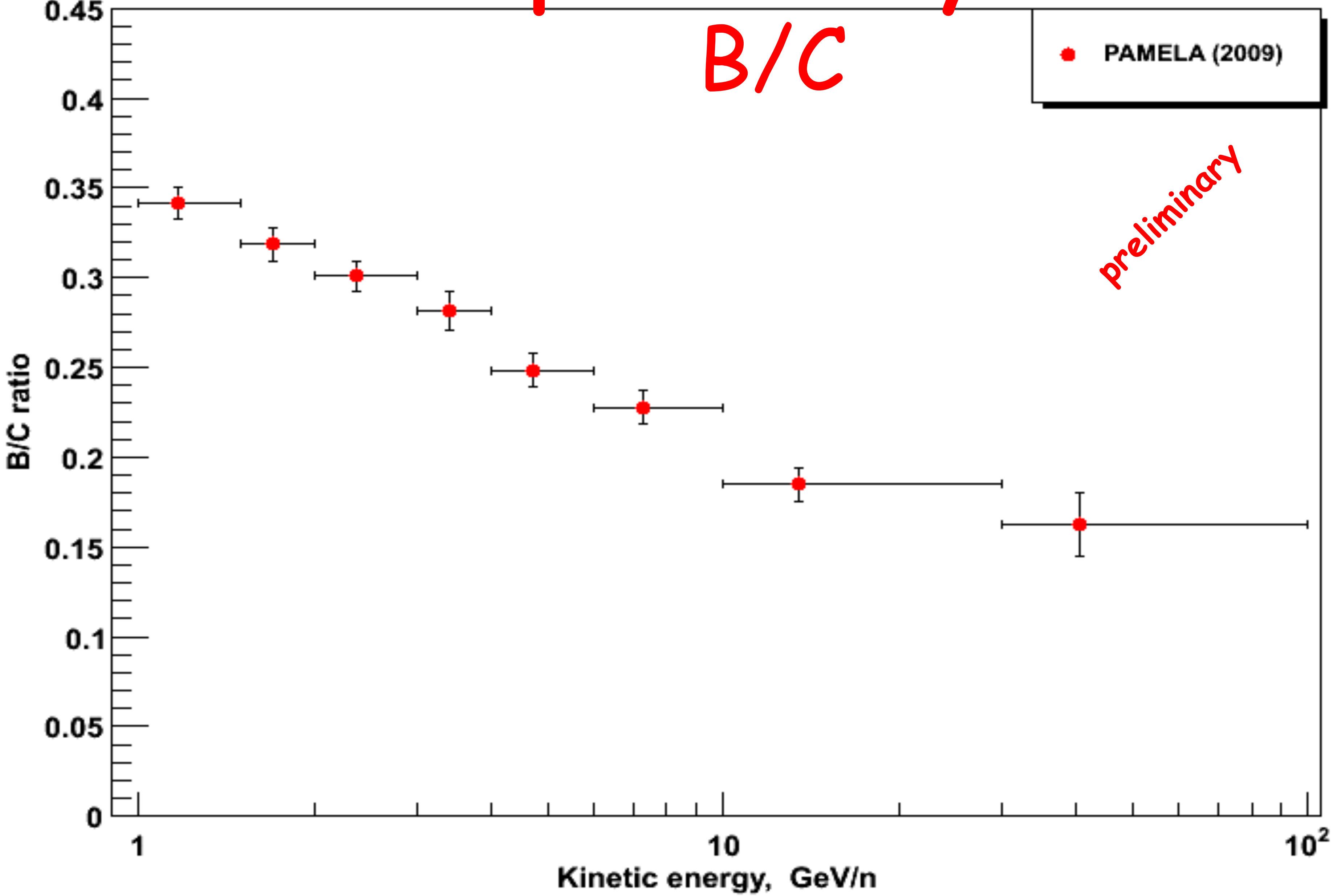


PAMELA preliminary results

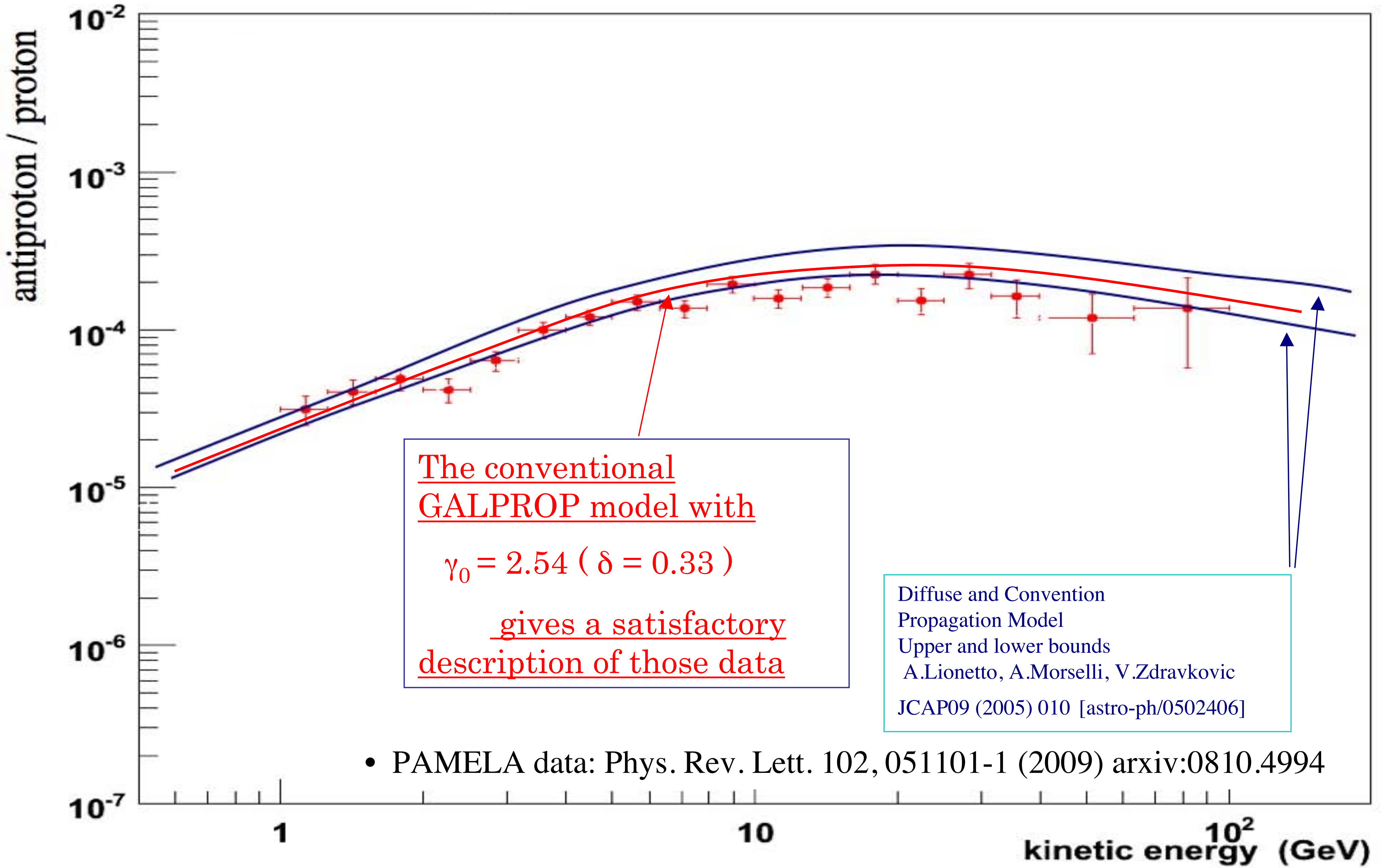


PAMELA preliminary results

B/C

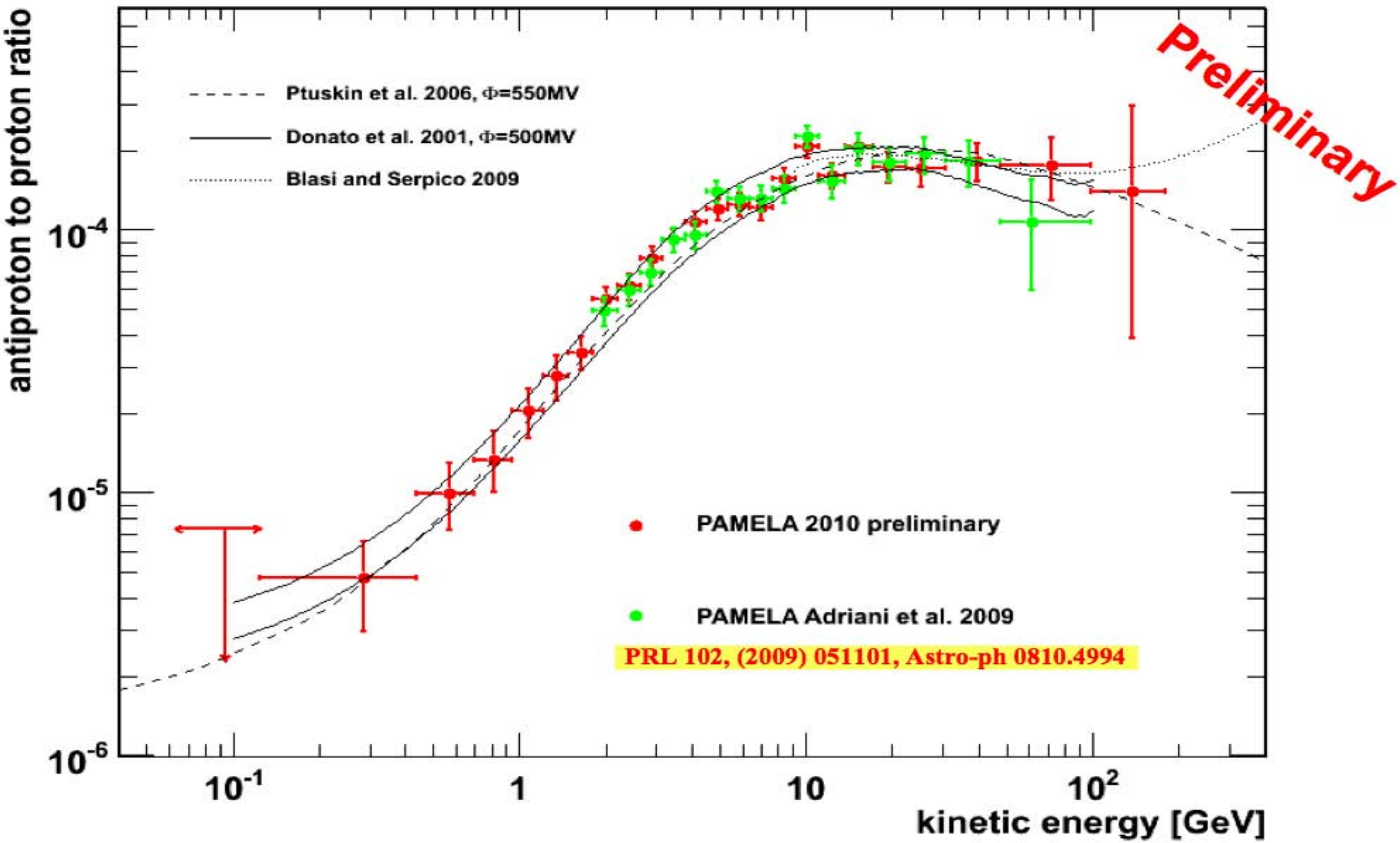


Antiproton-Proton Ratio

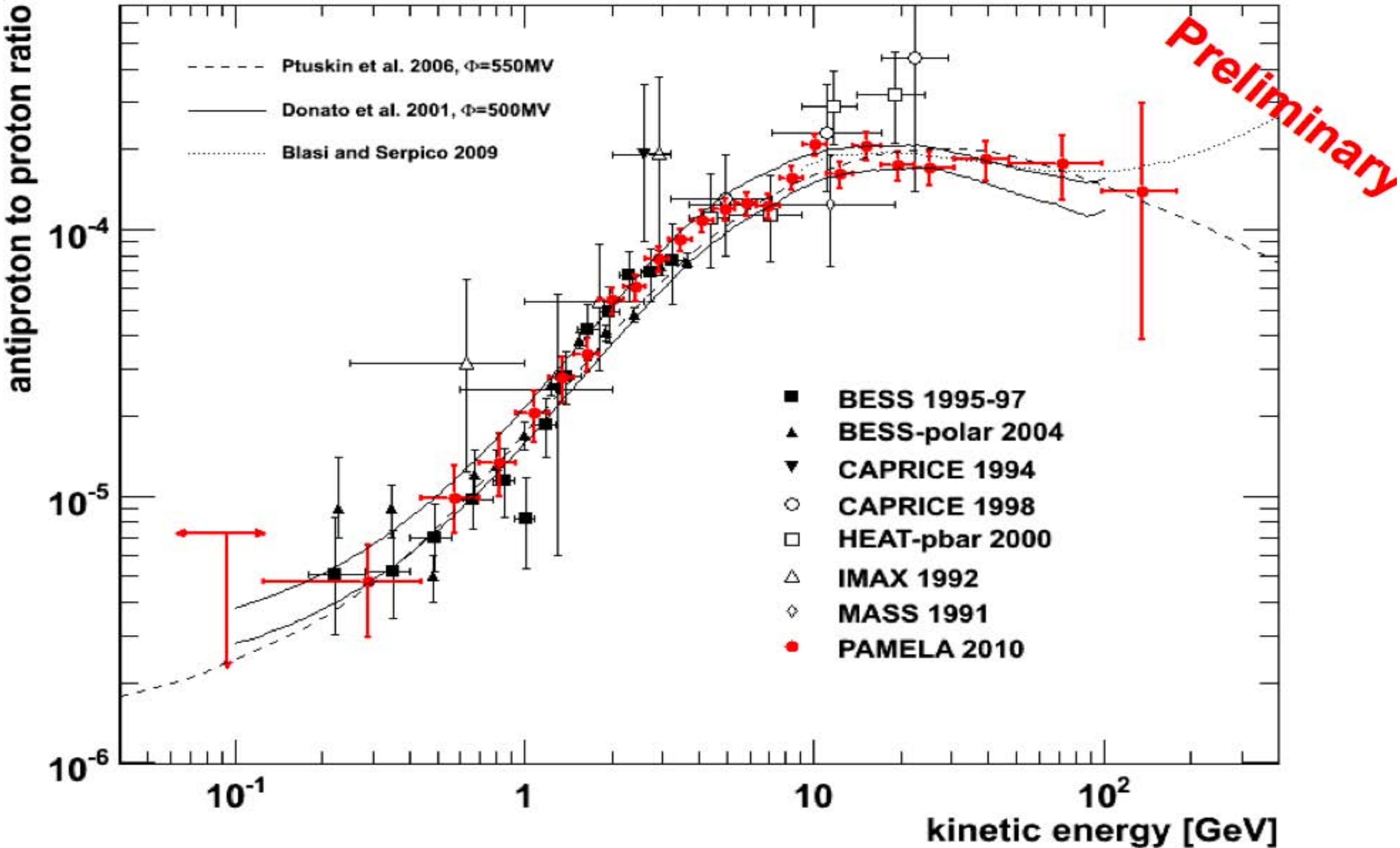


- PAMELA data: Phys. Rev. Lett. 102, 051101-1 (2009) arxiv:0810.4994

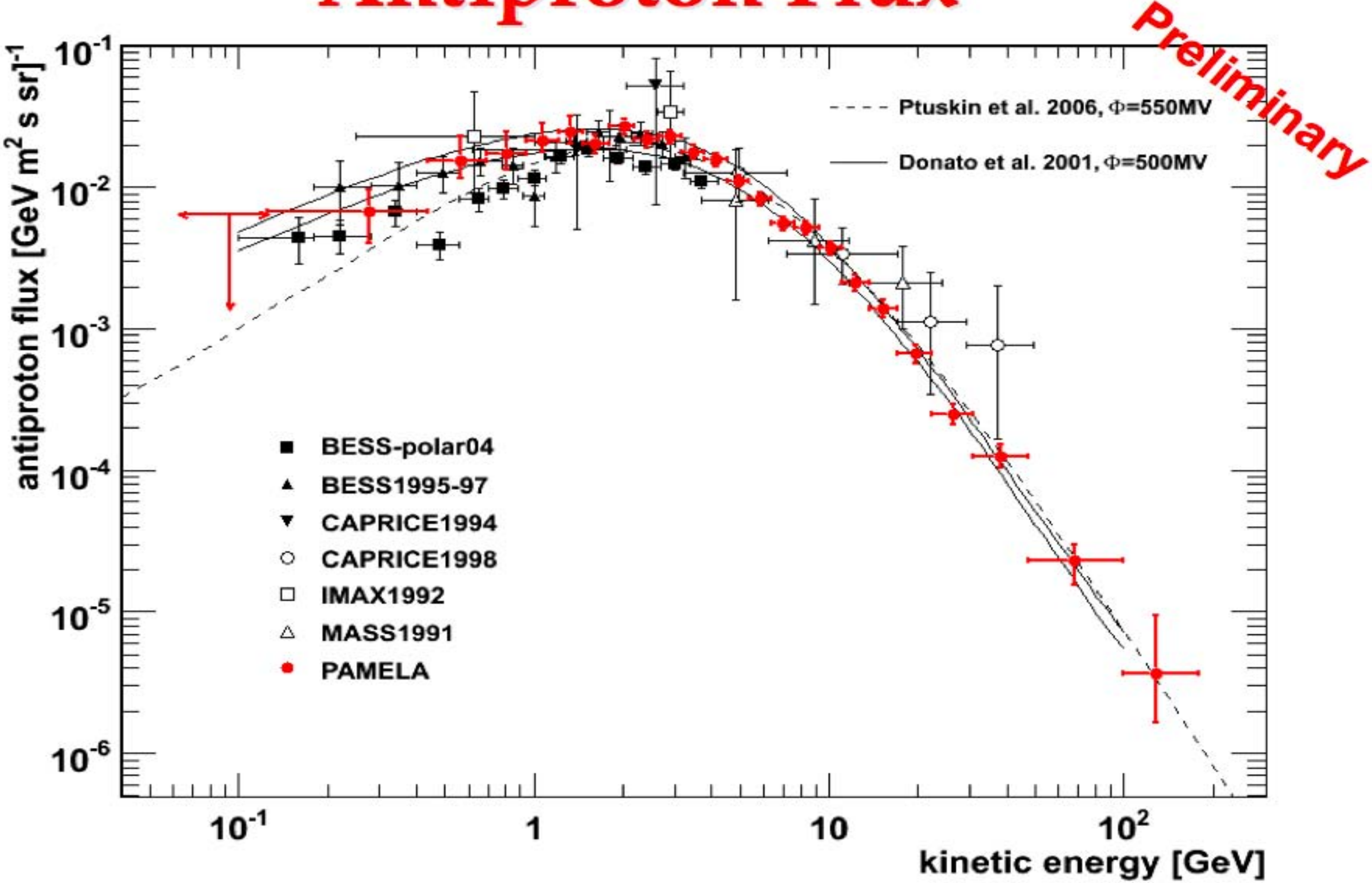
Antiproton-Proton Ratio



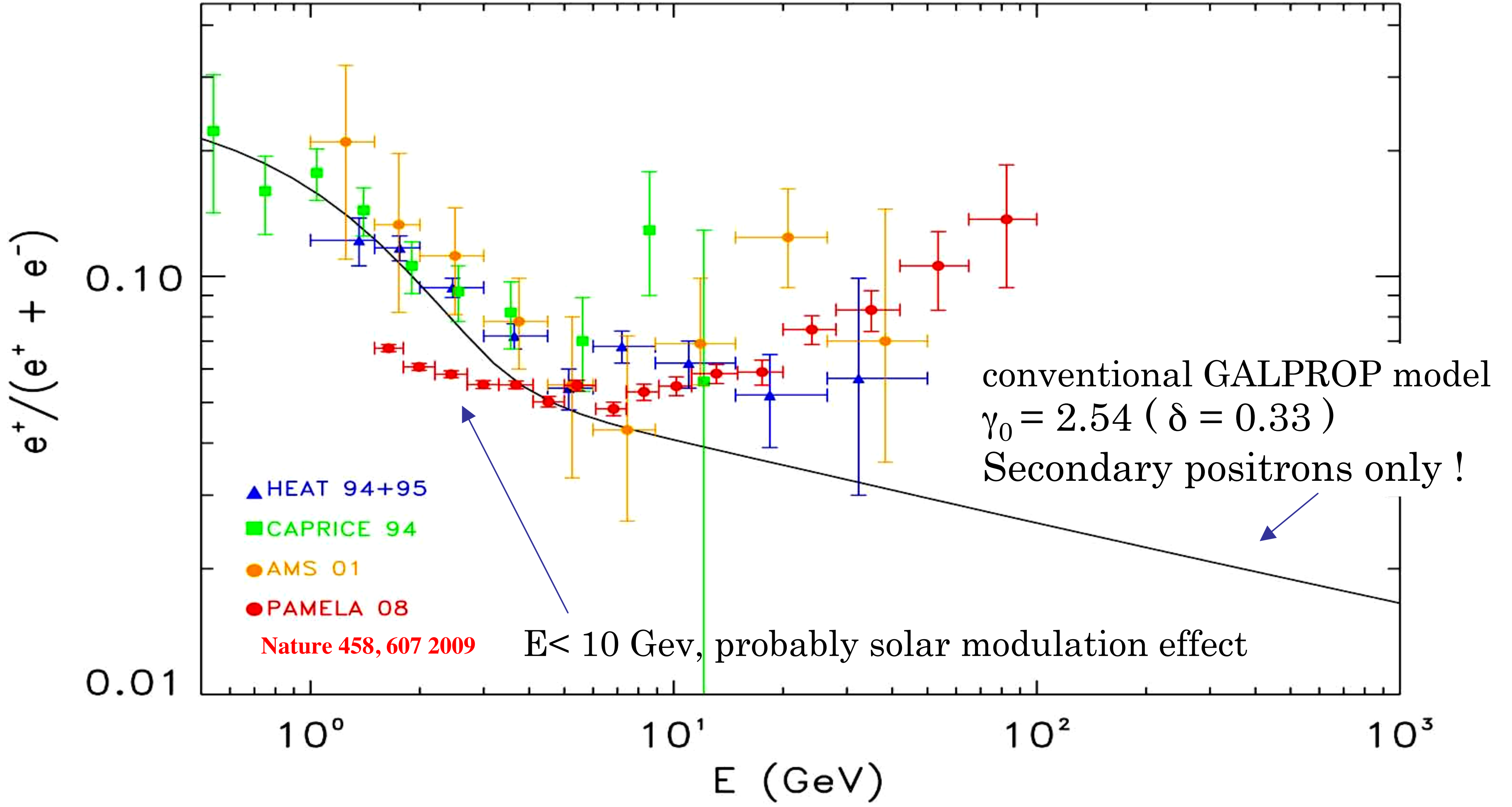
Antiproton-Proton Ratio



Antiproton Flux



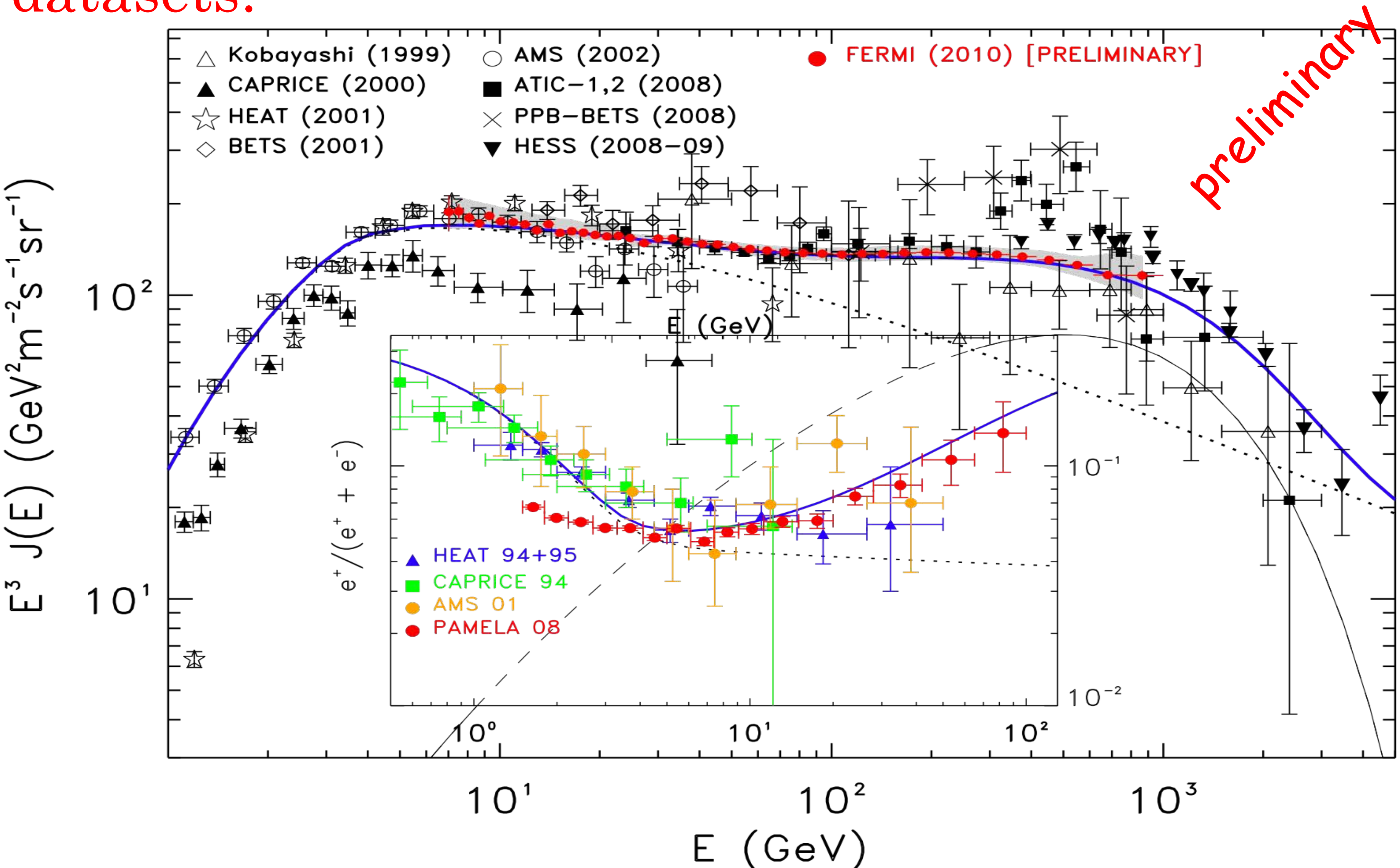
2009: Positron PAMELA results



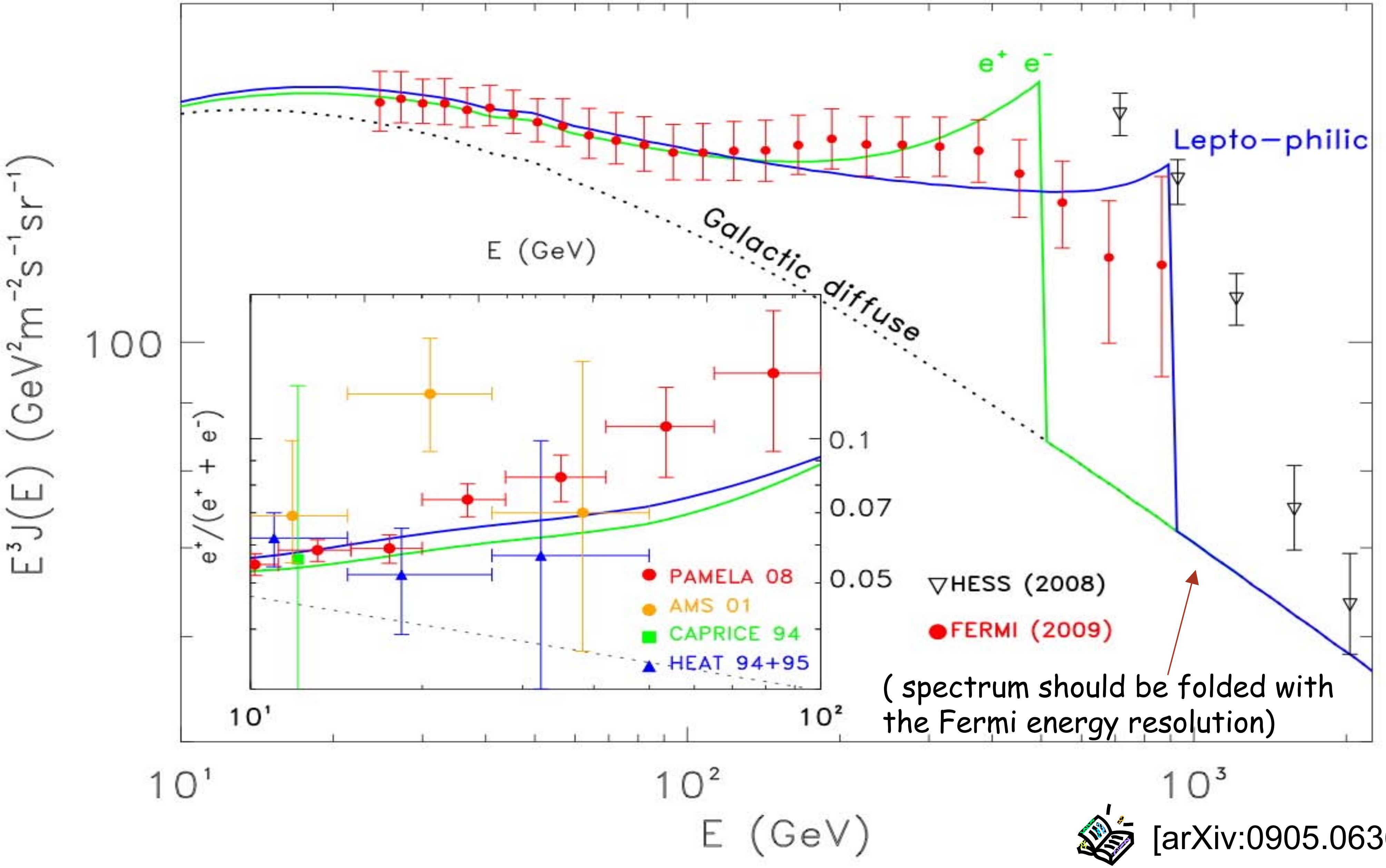
$e^+/(e^+ + e^-) \propto E^{-\gamma p + \gamma_0 - \delta}$ γp: proton source power-index

It improves only adopting very soft electron spectra (high γ_0)

An extra-component with injection index = 1.5 and an exponential cutoff at 1 TeV gives a good fit of all datasets!



Predictions for the CRE spectrum from two specific dark matter models

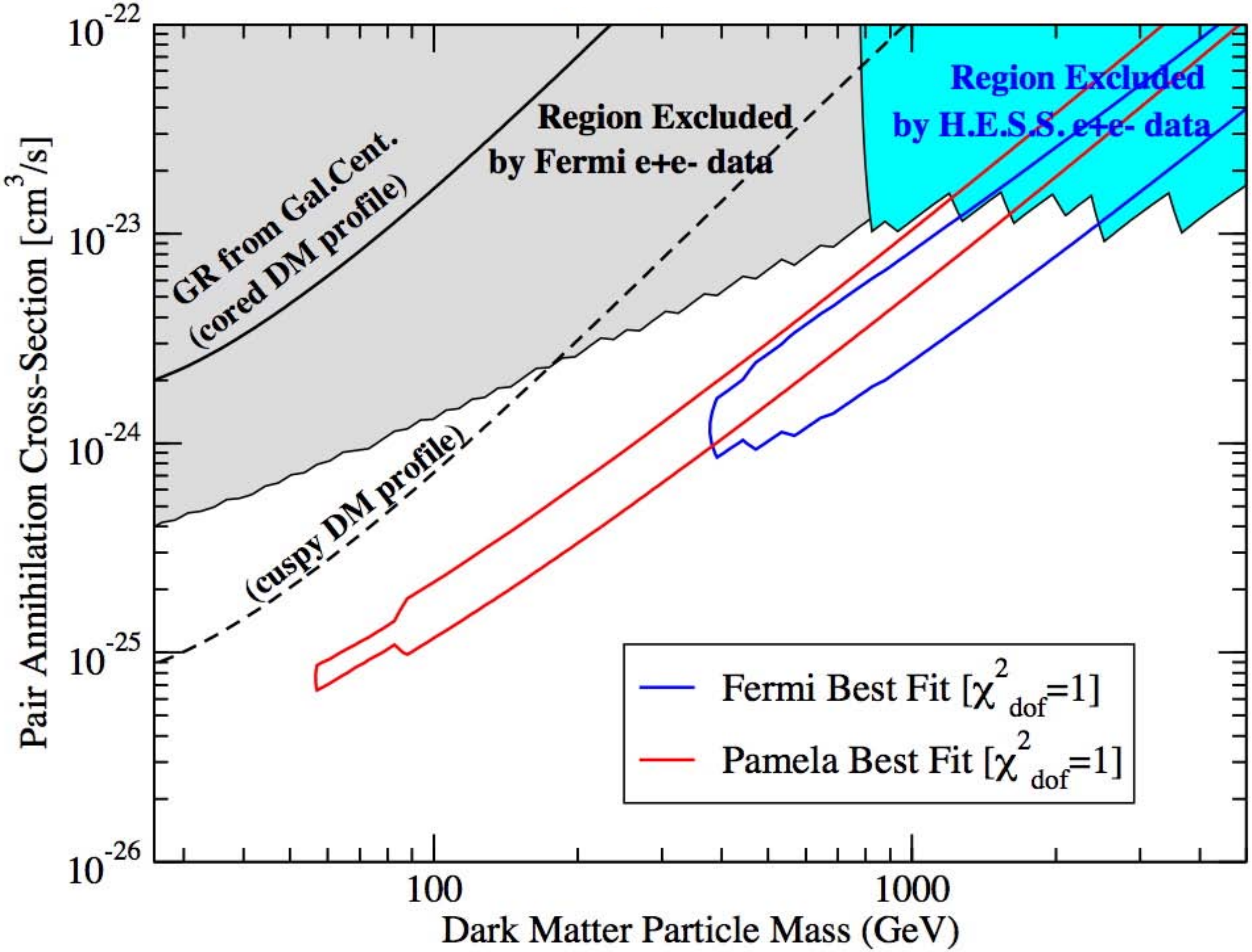


(spectrum should be folded with the Fermi energy resolution)

[arXiv:0905.0636]

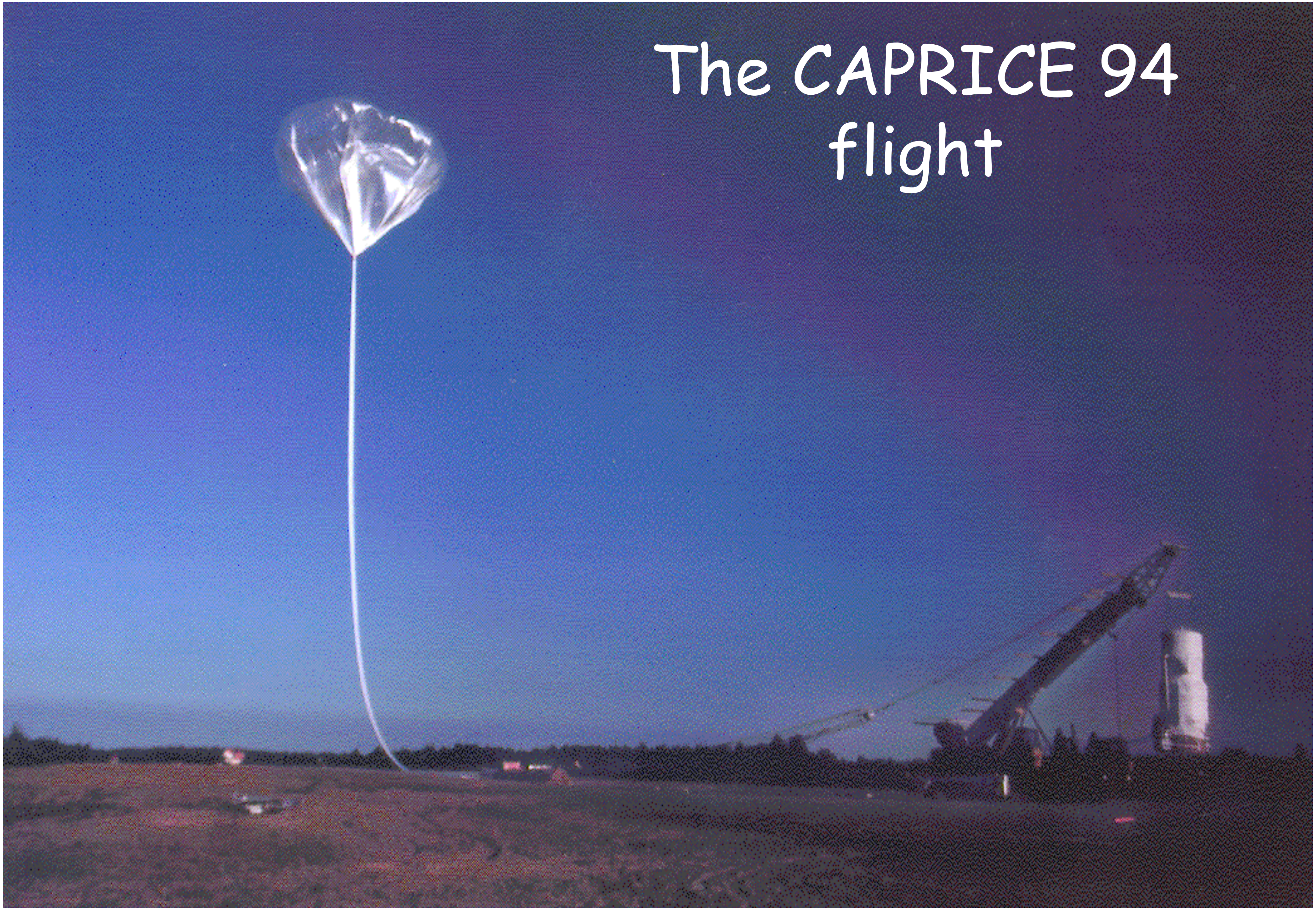
Lepto-philic Models

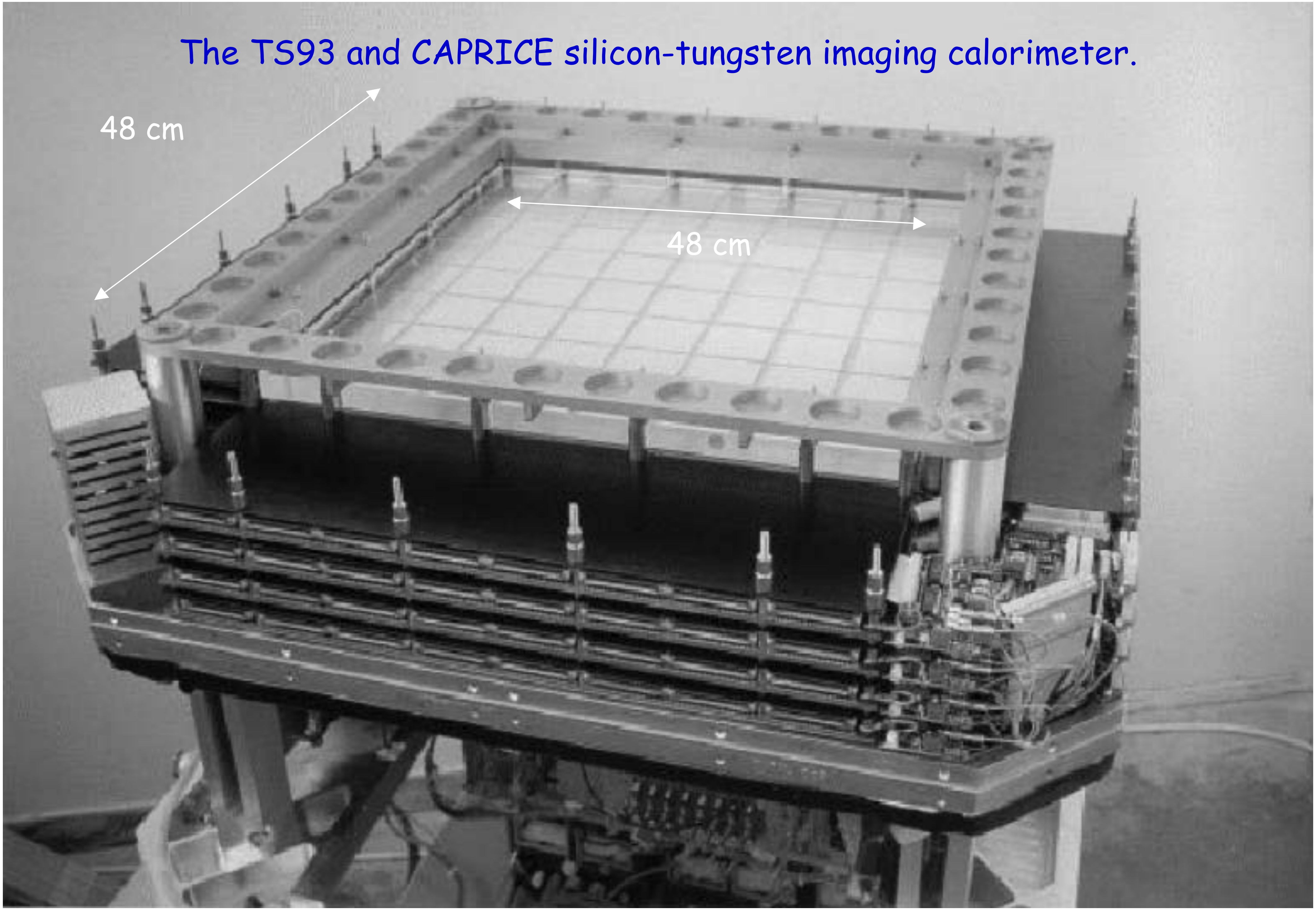
here we assume a democratic dark matter pair-annihilation branching ratio into each charged lepton species: 1/3 into e+e-, 1/3 into μ+ μ- and 1/3 into τ+τ-   Here too antiprotons are not produced in dark matter pair annihilation.



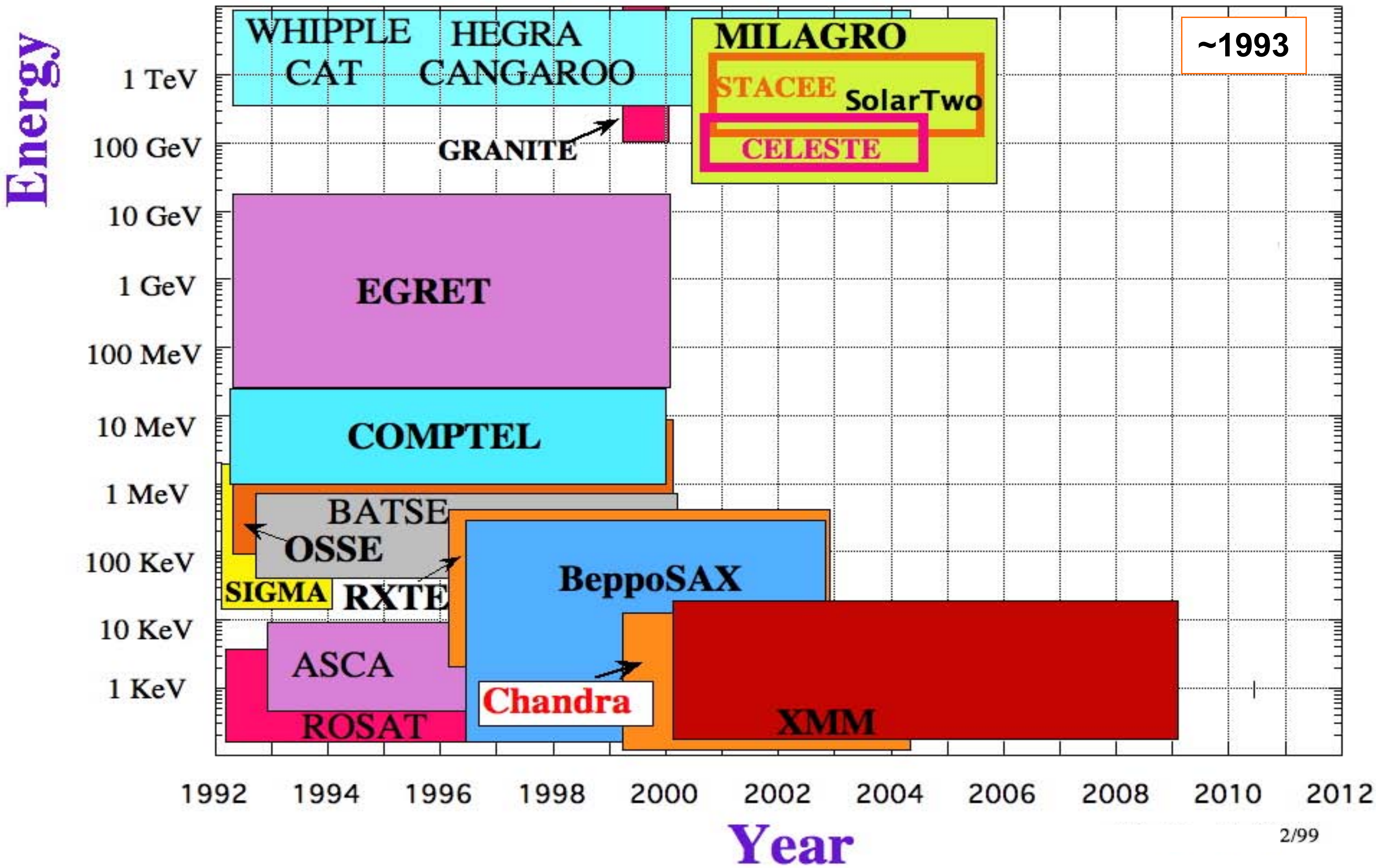
[arXiv:0905.0636]

models where dark matter only pair annihilates into charged leptons can give a satisfactory fit to the data for dark matter particle masses between 0.4 and 2 TeV, and for boost factors on the order of 10^2


The CAPRICE 94
flight


The TS93 and CAPRICE silicon-tungsten imaging calorimeter.
48 cm
48 cm

High Energy Gamma Experiments Experiments



ELSEVIER

Nuclear Instruments and Methods in Physics Research A 354 (1995) 547–552

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The GILDA mission: a new technique for a gamma-ray telescope in the energy range 20 MeV–100 GeV

G. Barbiellini [a], M. Boezio [a], M. Casolino [b], M. Candusso [b], M.P. De Pascale [b], A. Morselli [b,*], P. Picozza [b], M. Ricci [d], R. Sparvoli [b], P. Spillantini [c], A. Vacchi [a]

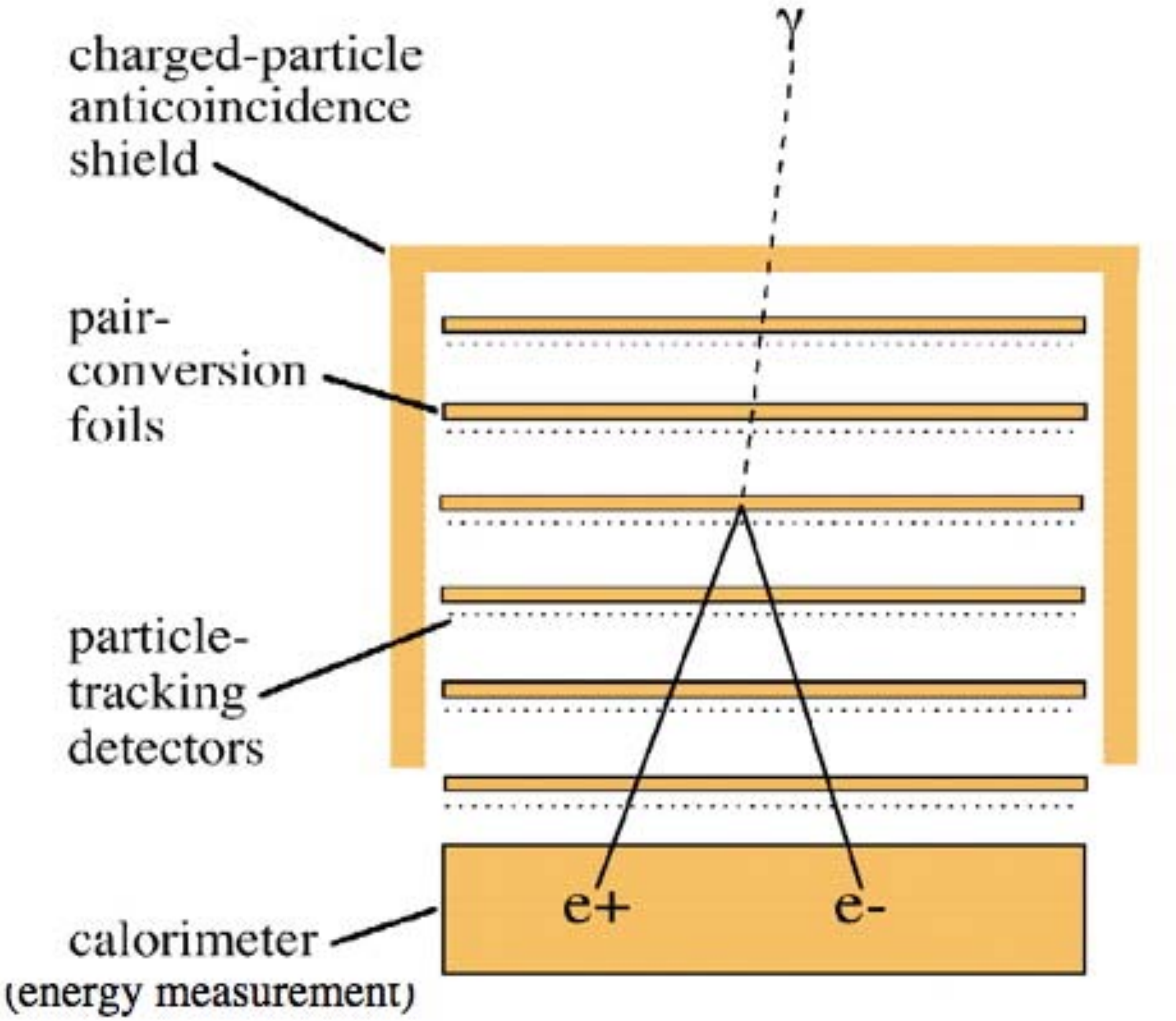
[a] *Dept. of Physics, Univ. of Trieste and INFN, Italy*
[b] *Dept. of Physics, II Univ. of Rome "Tor Vergata" and INFN, Italy*
[c] *Dept. of Physics, Univ. of Firenze and INFN, Italy*
[d] *INFN Laboratori Nazionali di Frascati, Italy*
* Corresponding author

Received 5 August 1994

Abstract

In this article a new technique for the realization of a high energy gamma-ray telescope is presented, based on the adoption of silicon strip detectors and lead scintillating fibers. The simulated performances of such an instrument (GILDA) are significatively better than those of EGRET, the last successful experiment of a high energy gamma-ray telescope, launched on the CGRO satellite, though having less volume and weight.

Elements of a pair-conversion telescope

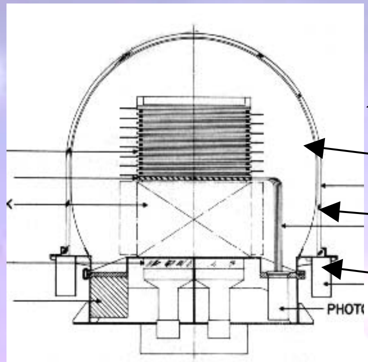


- photons materialize into matter-antimatter pairs:

  $E_{\gamma} \;\text{-->}\; m_{e^+}c^2 + m_{e^-}c^2$

- electron and positron carry information about the direction, energy and polarization of the γ-ray

SAS-2
11/1972-7/1973



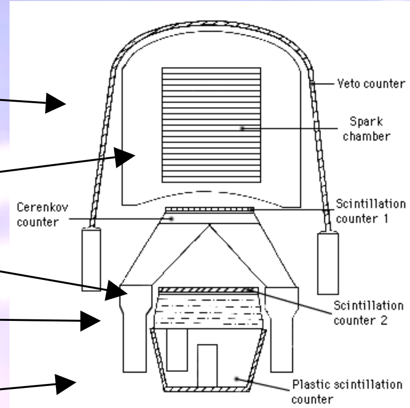
Anti-Coincidence Dome

Spark Chamber

Trigger Telescope

Cerenkov Counter

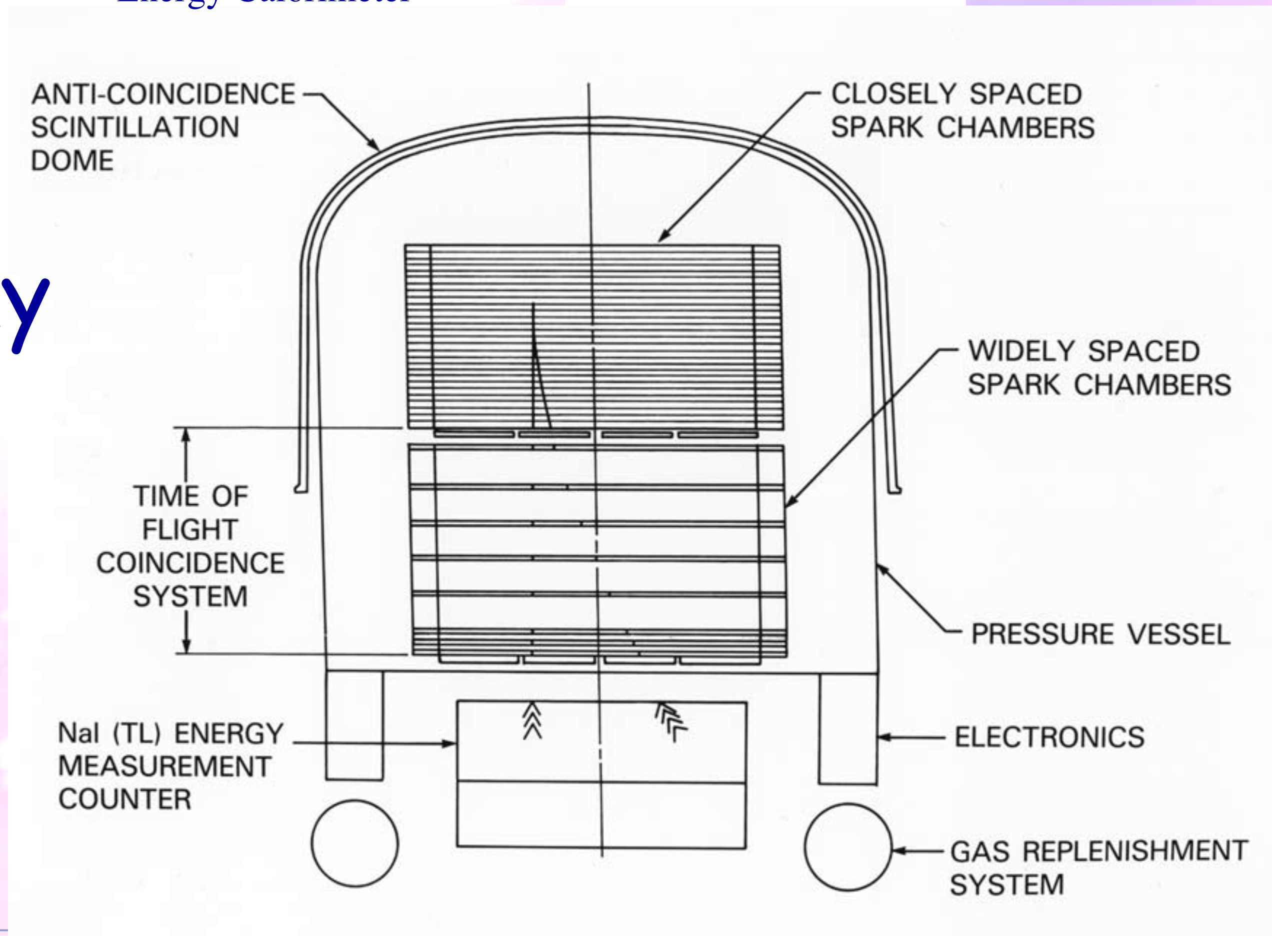
Energy Calorimeter

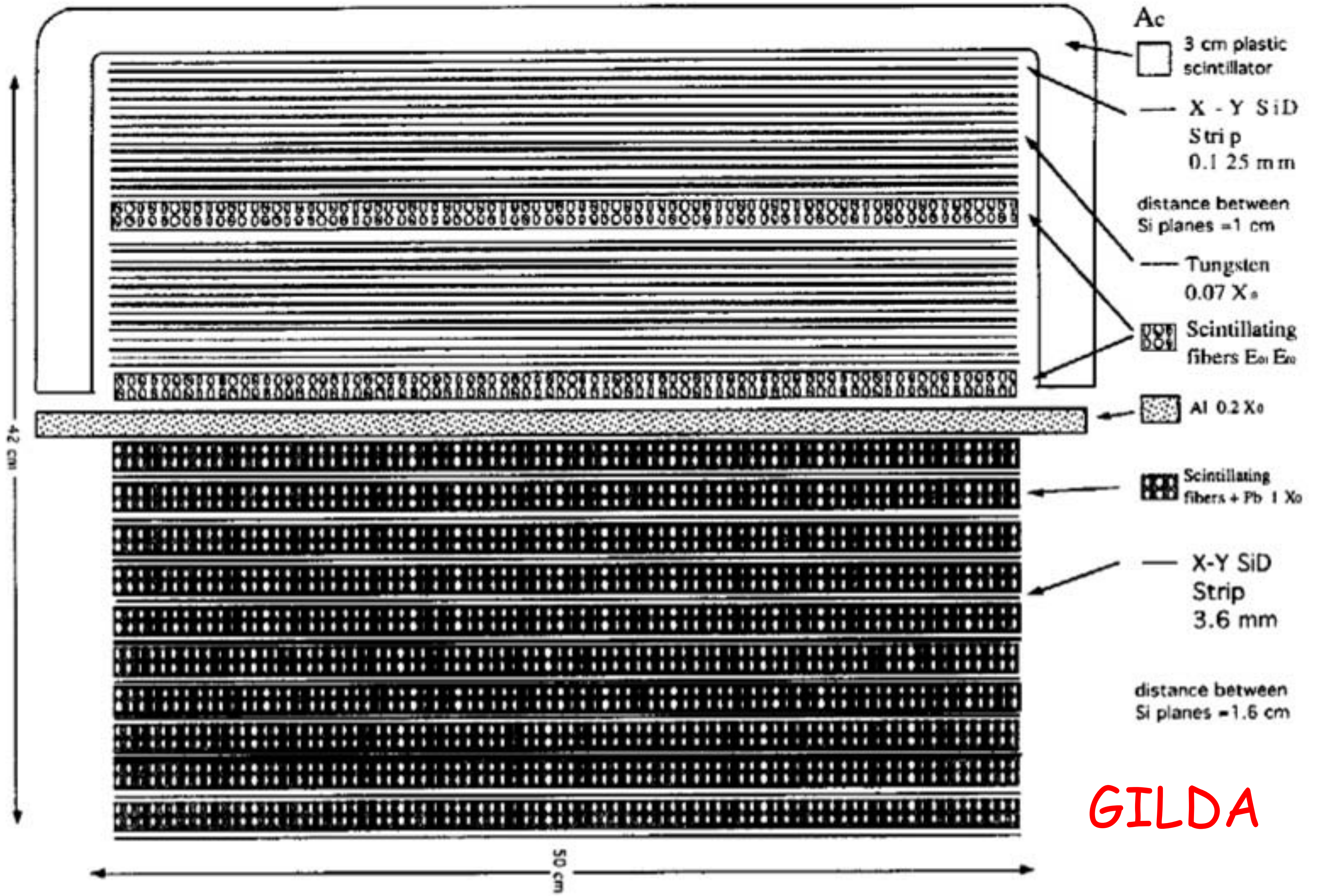


Cos-B
8/1975-4/1982

The gamma-ray missions

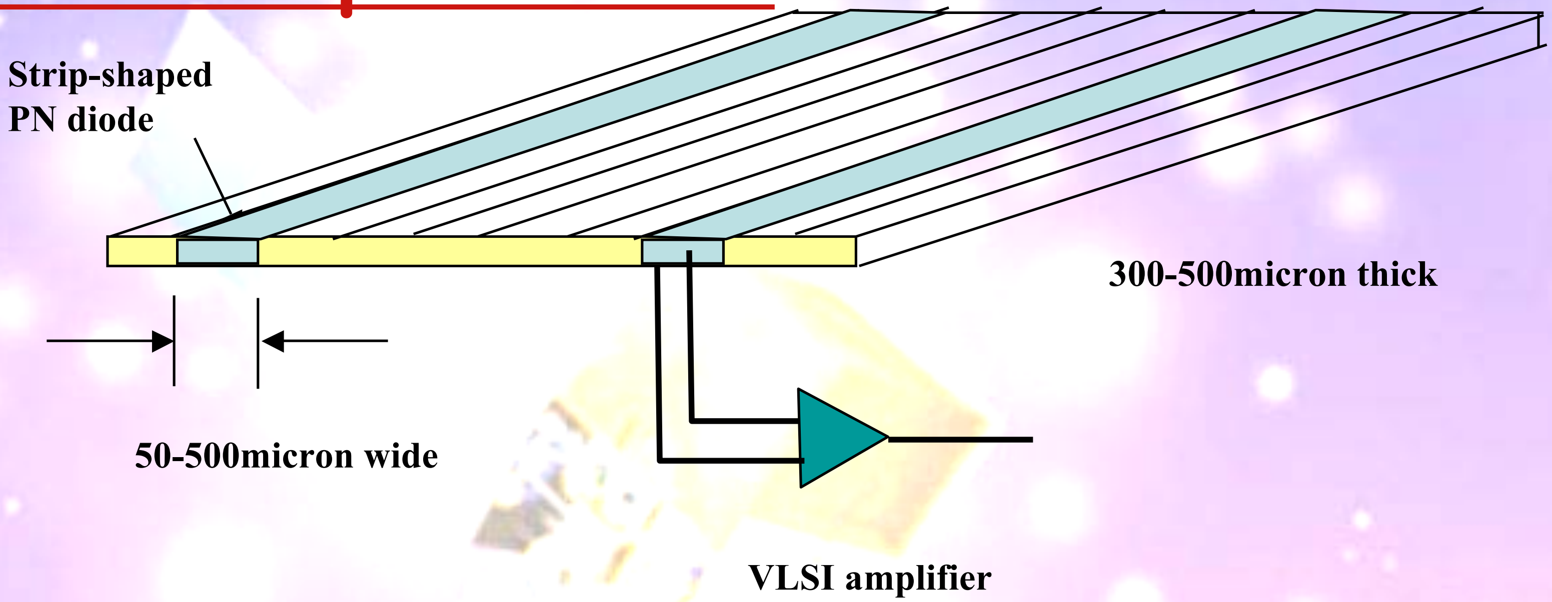
EGRET
4/1991-1999




Ac
3 cm plastic scintillator
X - Y SiD Strip 0.125 mm
distance between Si planes =1 cm
Tungsten 0.07 X0
Scintillating fibers E01 E0
Al 0.2 X0
Scintillating fibers + Pb 1 X0
X-Y SiD Strip 3.6 mm
distance between Si planes =1.6 cm
42 cm
50 cm
GILDA

New Detector Technology

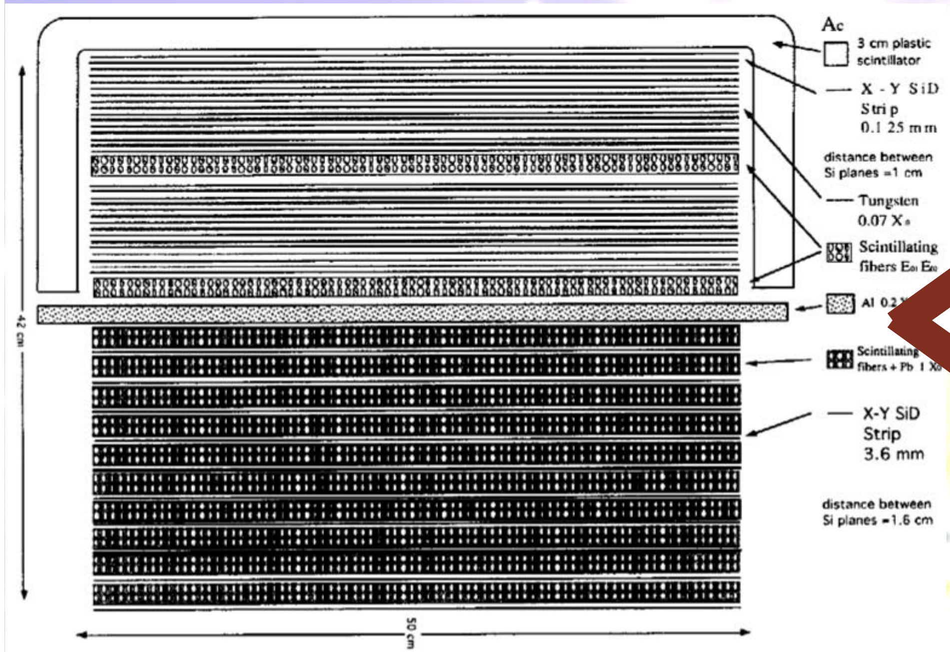
- <u>Silicon strip detector</u>



Stable particle tracker that allows micron-level tracking of gamma-rays

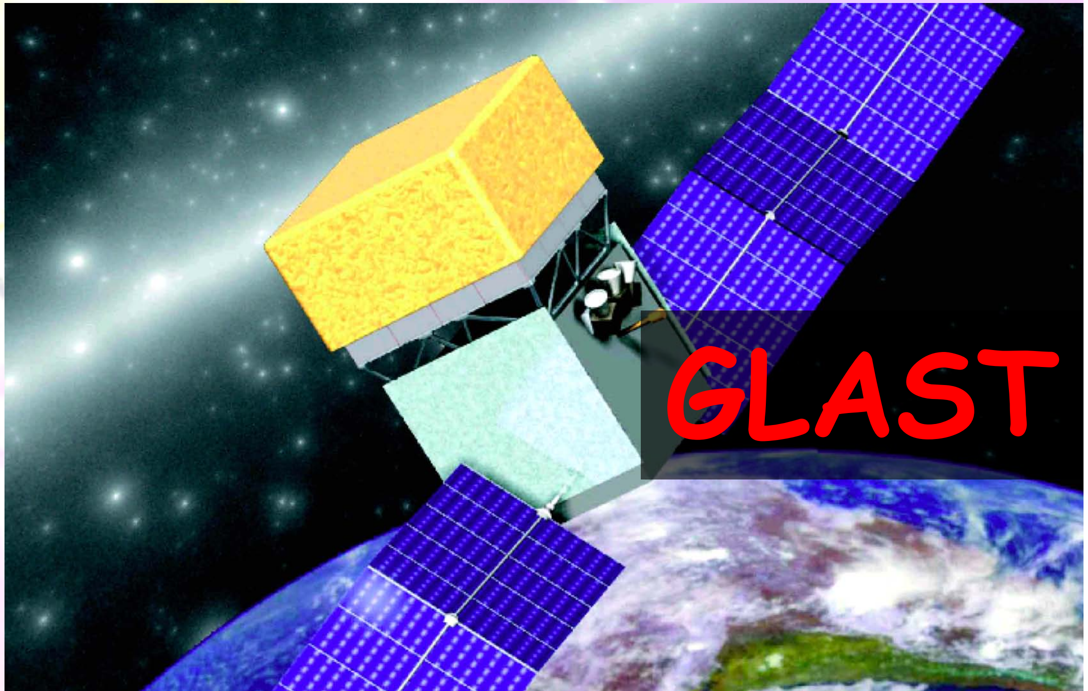
Well known technology in Particle Physics experiments.
Used by our collaboration in balloon experiments (MASS, TS93, CAPRICE), on MIR Space Station (SilEye) and on satellite (NINA)

GILDA



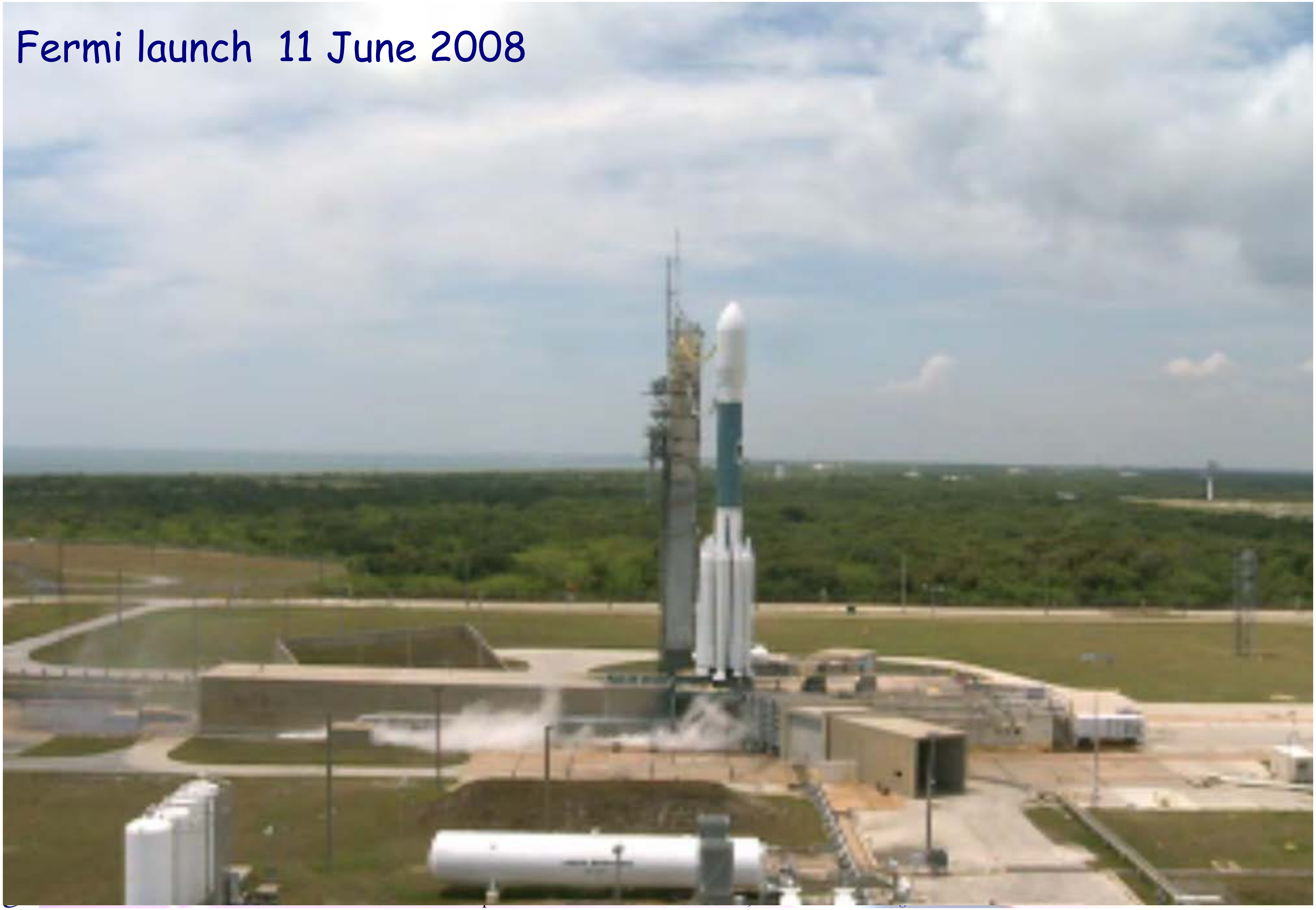
Ac
3 cm plastic scintillator
X - Y SiD Strip 0.1 25 mm
distance between Si planes =1 cm
Tungsten 0.07 X₀
Scintillating fibers
Al 0.2
Scintillating fibers + Pb 1 X₀
X-Y SiD Strip 3.6 mm
distance between Si planes =1.6 cm
42 cm
50 cm

agile
Astro-rivelatore Gamma
a Immagini Leggero
INAF
INFN
Alenia
telespazio



GLAST

Fermi launch 11 June 2008



Search Strategies

Satellites:

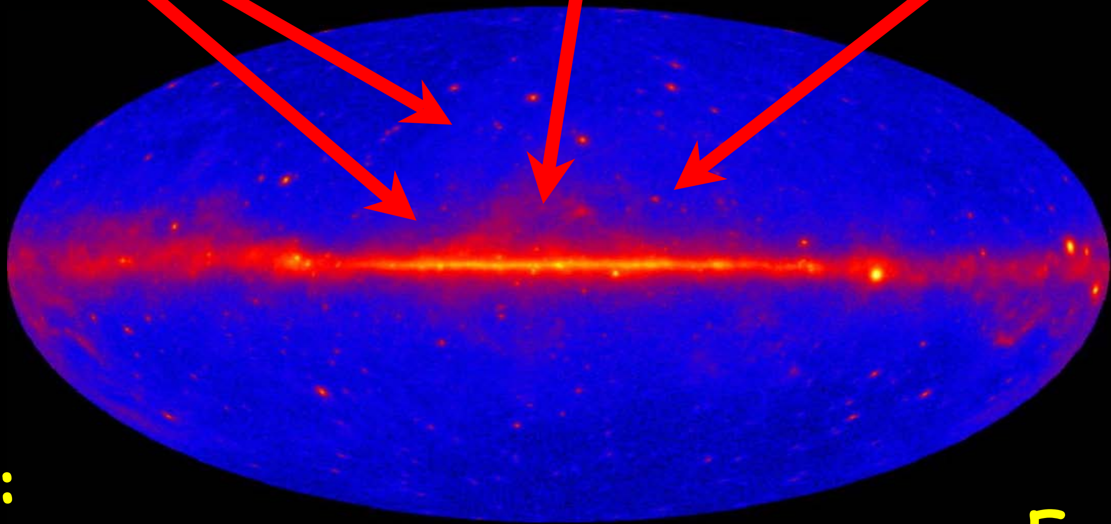
Low background and good source id, but low statistics

Galactic center:

Good statistics but source confusion/diffuse background

Milky Way halo:

Large statistics but diffuse background



And electrons!

and Anisotropies

Spectral lines:

No astrophysical uncertainties, good source id, but low statistics

Galaxy clusters:

Low background but low statistics

Extra-galactic:

Large statistics, but astrophysics,galactic diffuse background

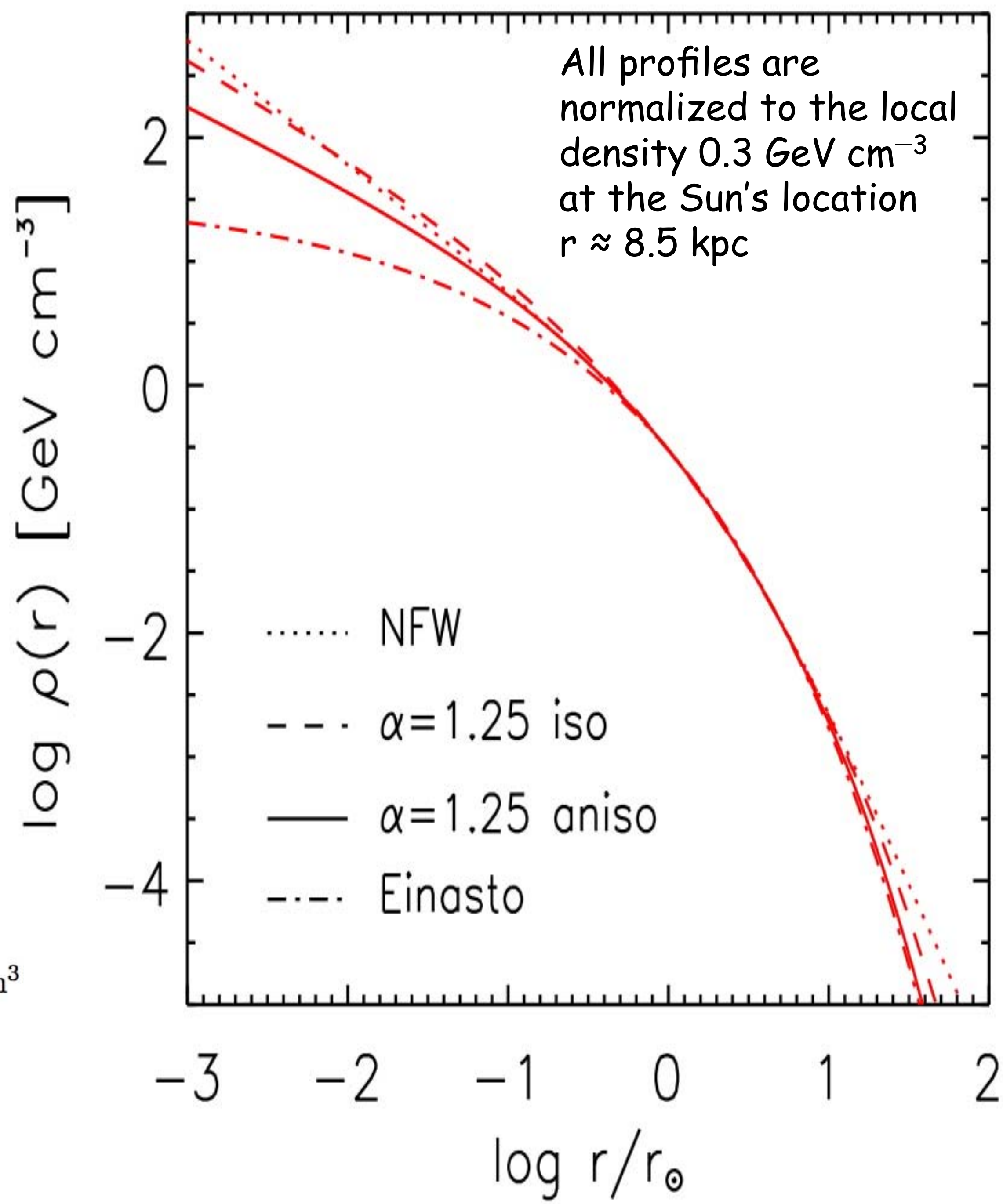
Pre-launch sensitivities published in Baltz et al., 2008, JCAP 0807:013 [astro-ph/0806.2911]

Milky Way Dark Matter Profiles

$$\rho(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1 + (r_\odot/r_s)^\alpha}{1 + (r/r_s)^\alpha}\right]^{(\beta-\gamma)/\alpha}$$

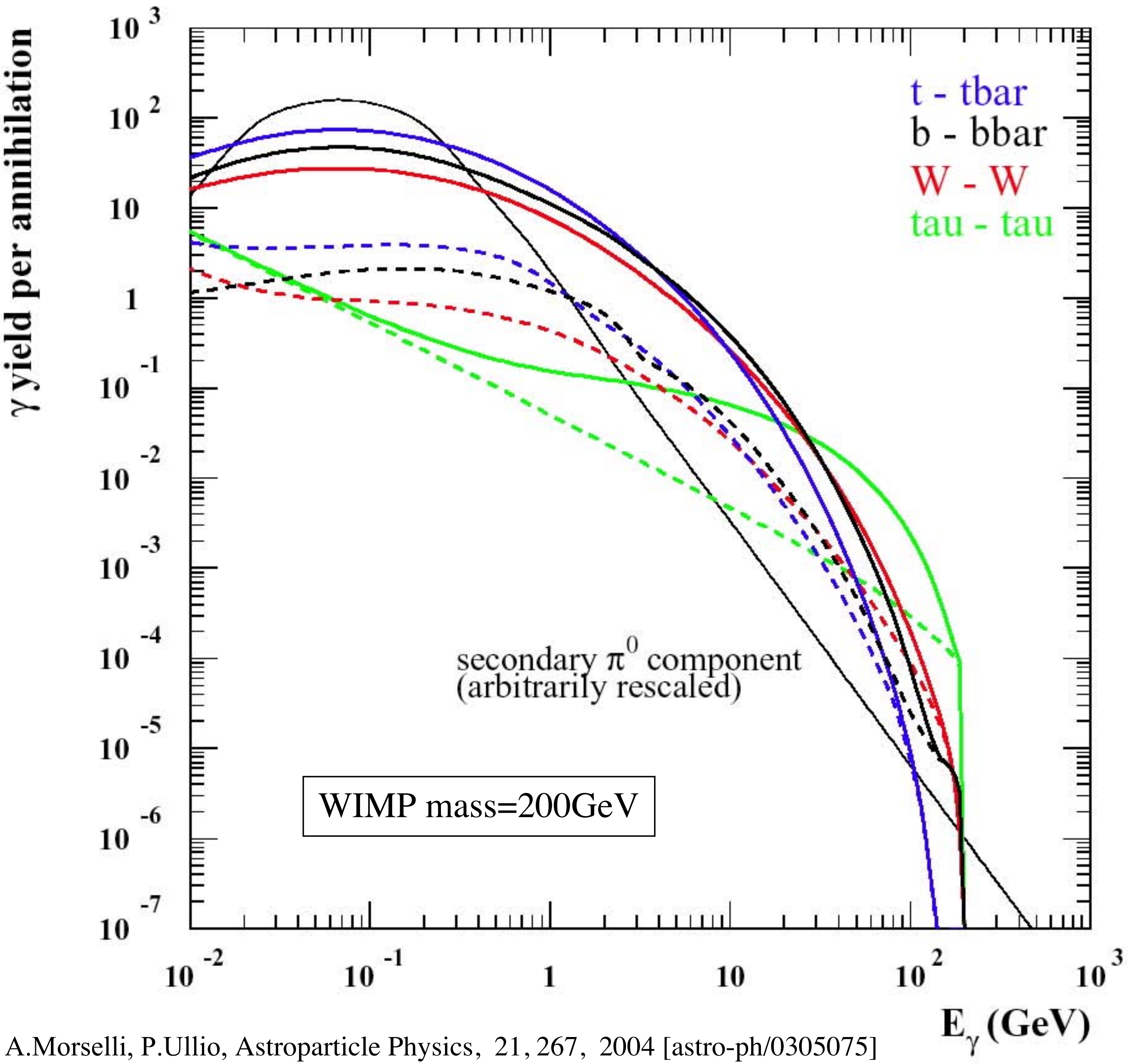
Halo model	α	β	γ	r_s in kpc
Cored isothermal	2	2	0	5
Navarro, Frenk, White	1	3	1	20
Moore	1	3	1.16	30

Einasto | $\alpha = 0.17$ $r_s = 20\,\mathrm{kpc}$ $\rho_s = 0.06\,\mathrm{GeV/cm^3}$



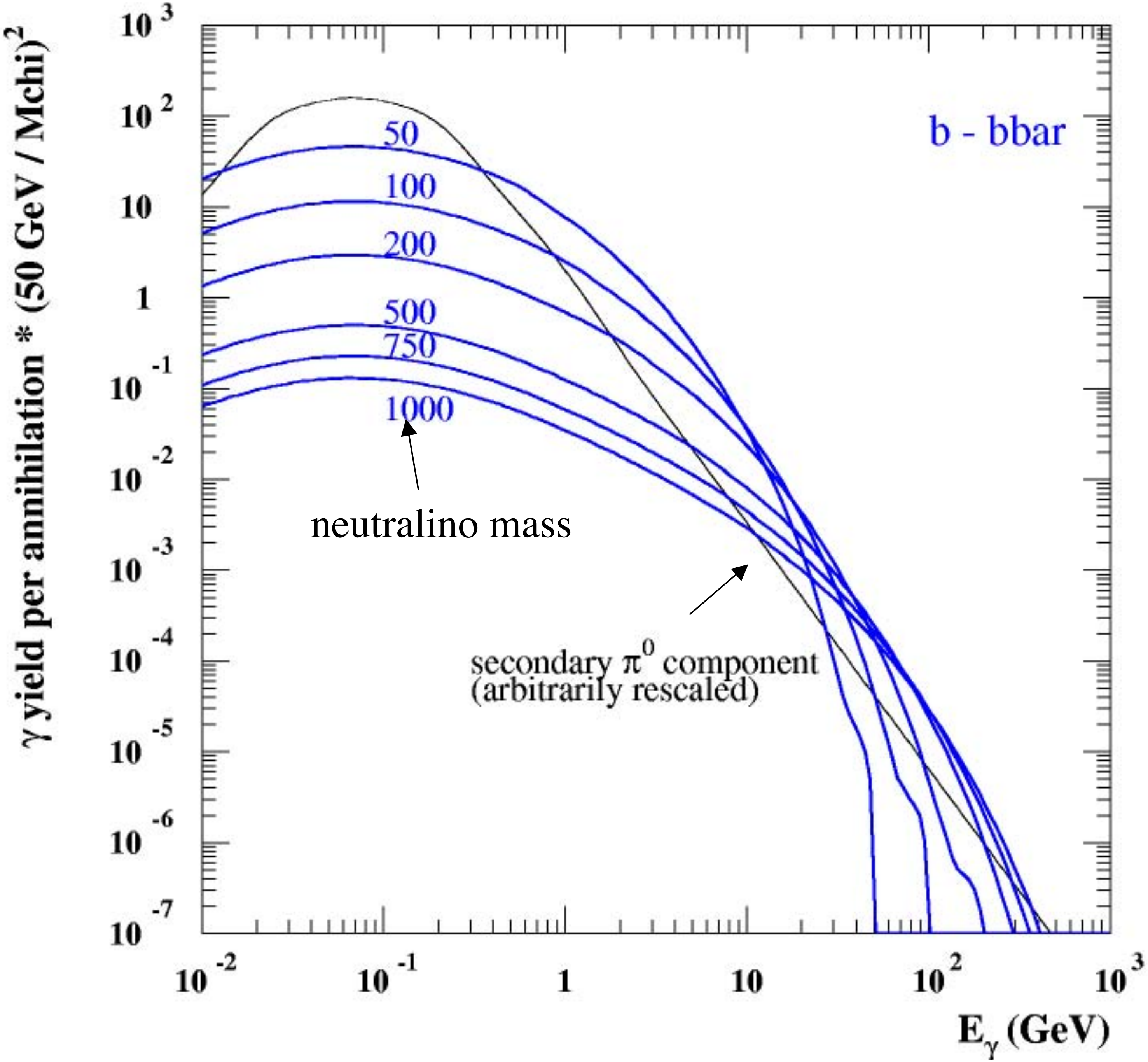
A.Lapi et al. arXiv:0912.1766

Differential yield for each annihilation channel



A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267, 2004 [astro-ph/0305075]

Differential yield for b bar

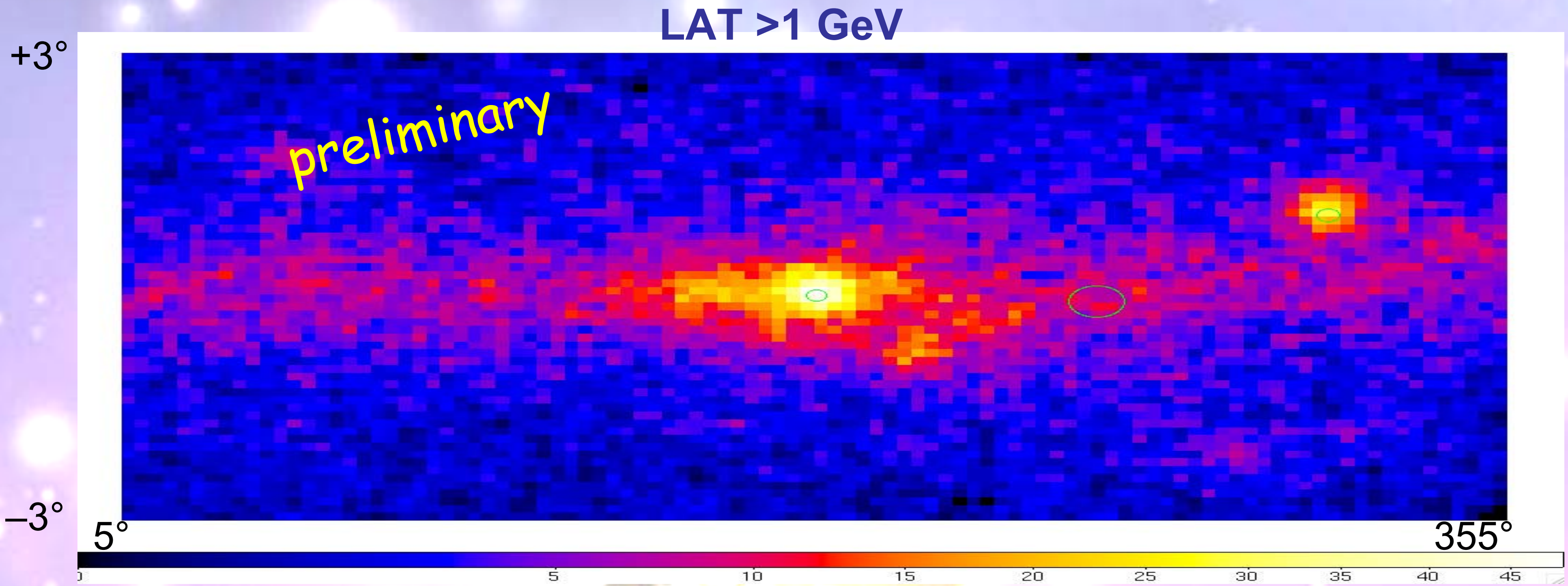


A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, 2004 [astro-ph/0305075]

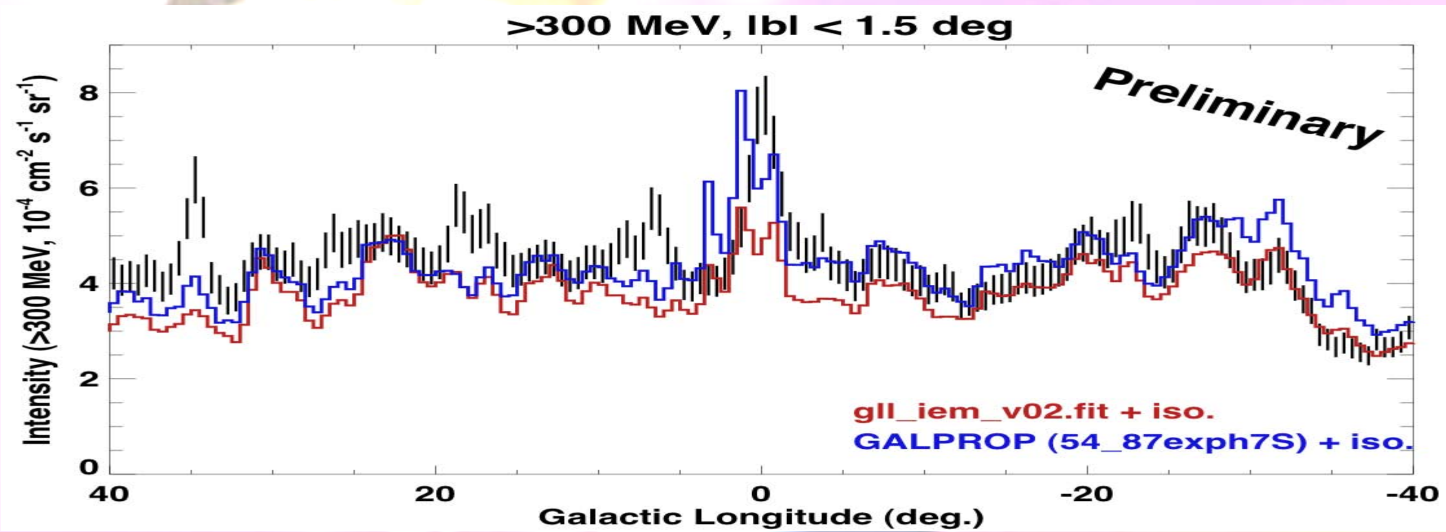
Search for Dark Matter in the Galactic Center

- Steep DM profiles ⇒ Expect large DM annihilation/decay signal from the GC!
- Good understanding of the astrophysical background is crucial to extract a potential DM signal from this complicated region of the sky:
  - source confusion: energetic sources near to or in the line of sight of the GC
  - diffuse emission modeling: uncertainties in the integration over the line of sight in the direction of the GC, very difficult to model

Fermi LAT Observations of the GC

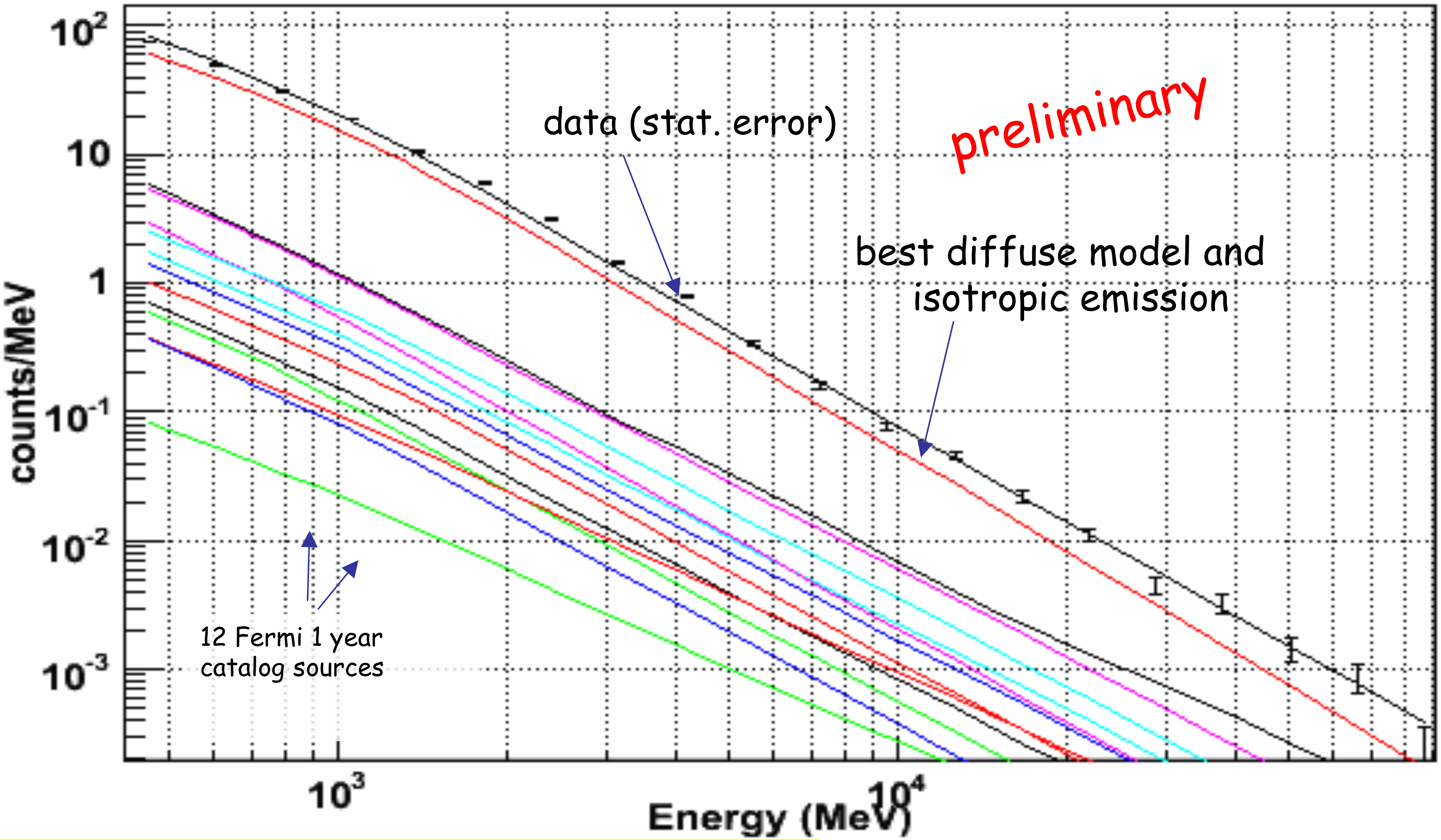


12-month data set, Diffuse class, **Front** only
smoothed with σ = 0.1°
BSL source location circles overlaid



Fermi LAT Coll. in preparation

Spetrum (E> 400 MeV, 7°x7° region centered on the Galactic Center analyzed with binned likelihood analysis)

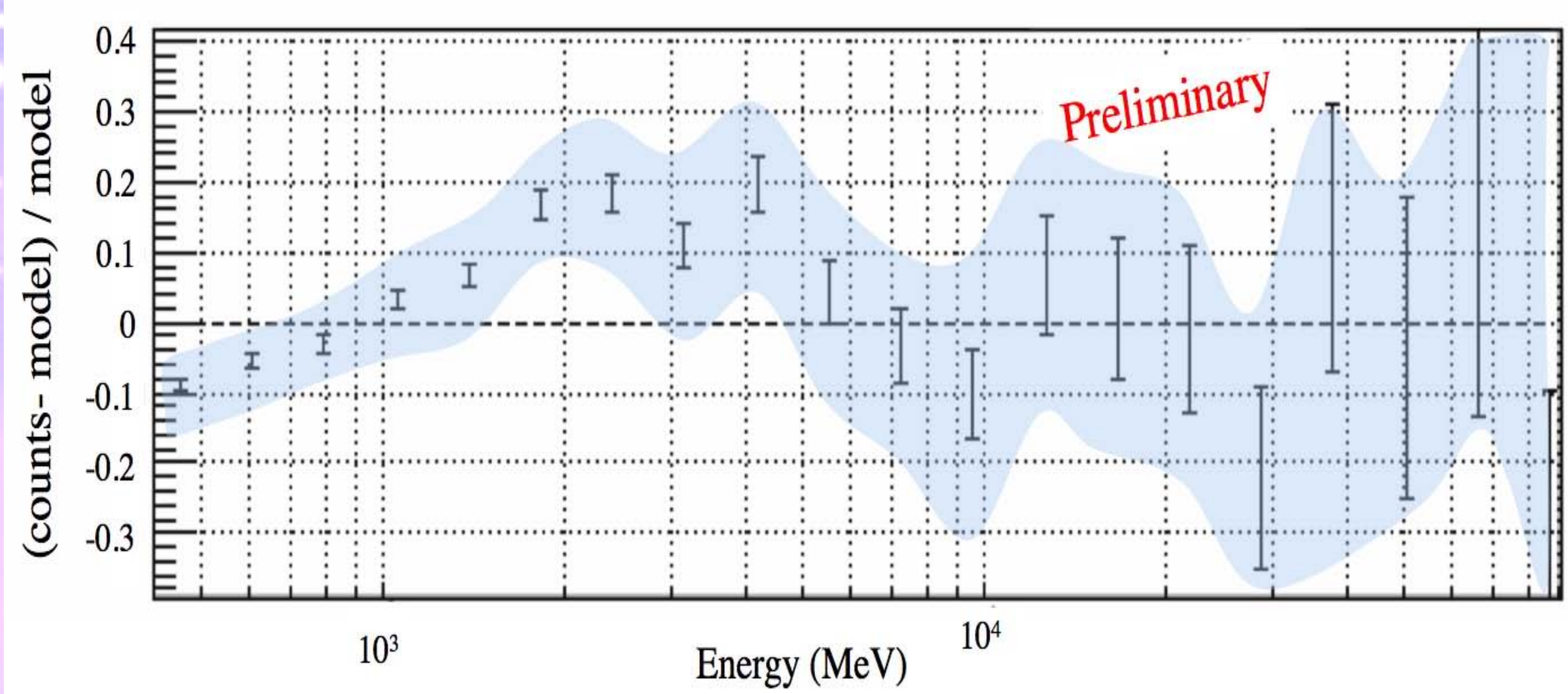


Fermi LAT Coll. in preparation, Fermi Symp. arXiv:0912.3828

GC Residuals 7°x7° region centered on the Galactic Center

11 months of data, E >400 MeV, front-converting events analyzed with binned likelihood analysis)

- The systematic uncertainty of the effective area (blue area) of the LAT is ~10% at 100 MeV, decreasing to 5% at 560 MeV and increasing to 20% at 10 GeV



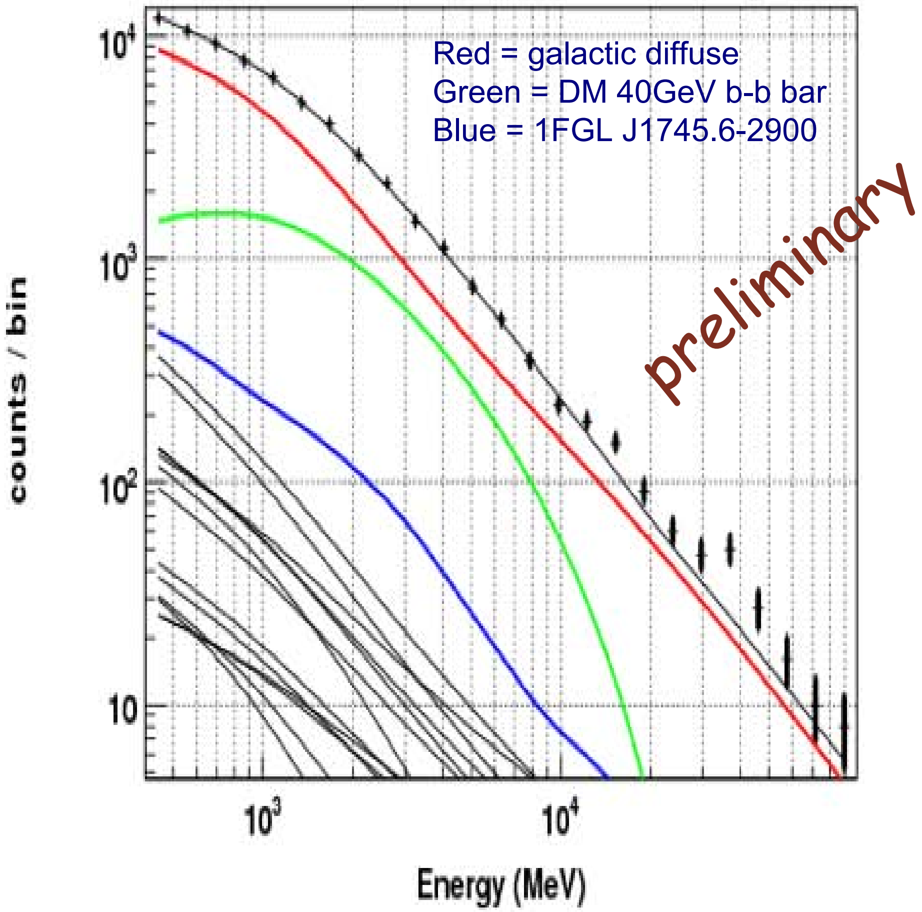
Fermi LAT Coll. in preparation, Fermi Symp. arXiv:0912.3828

Search for Dark Matter in the Galactic Center

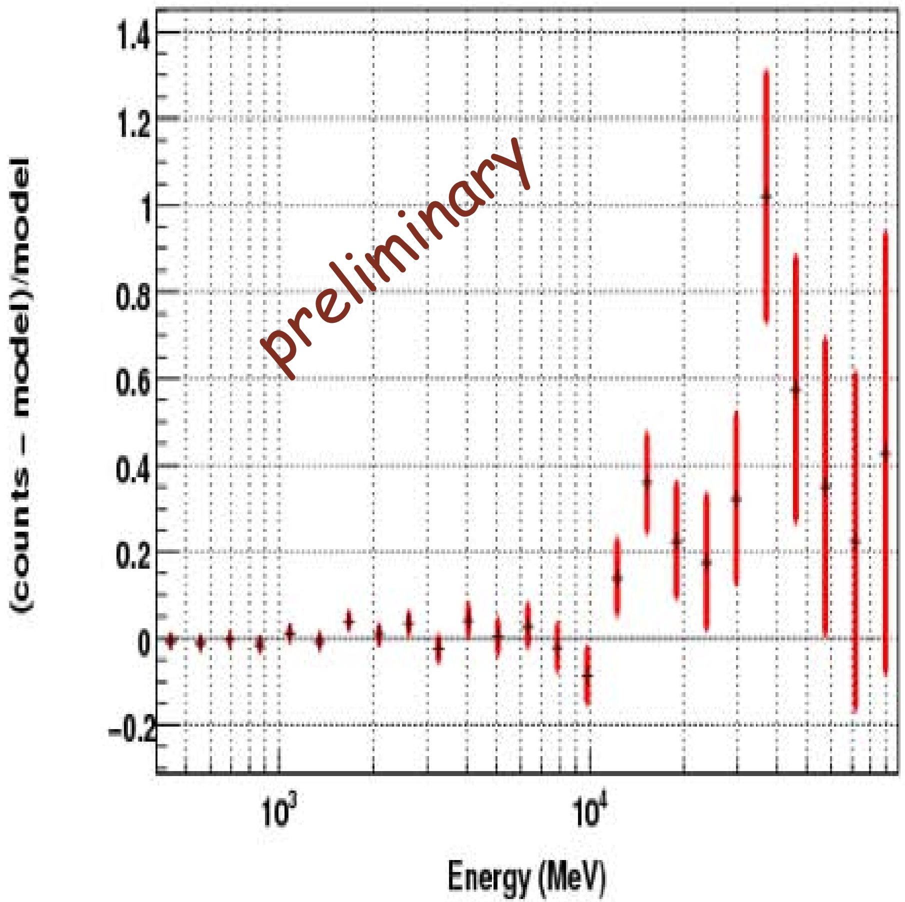
- Model generally reproduces data well within uncertainties. The model somewhat under-predicts the data in the few GeV range (spatial residuals under investigation)
- Any attempt to disentangle a potential dark matter signal from the galactic center region requires a detailed understanding of the conventional astrophysics and instrumental effects
- More prosaic explanations must be ruled out before invoking a contribution from dark matter if an excess is found (e.g. modeling of the diffuse emission, unresolved sources, ...)
- Analysis in progress to updated constraints on annihilation cross section

One of the Possible Explanations

Counts Spectra of the model components

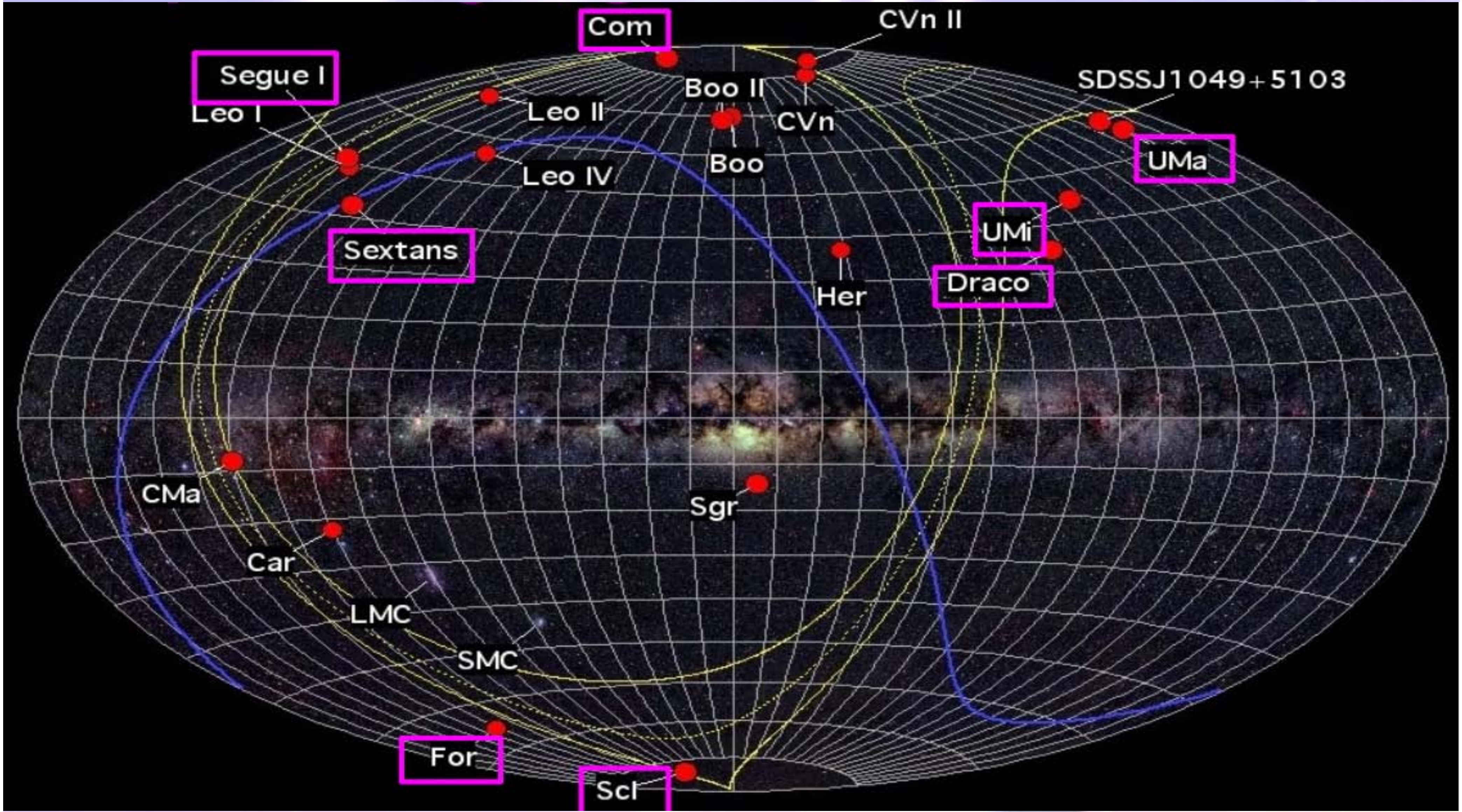


Residuals: (Exp.Data- Model)/Model

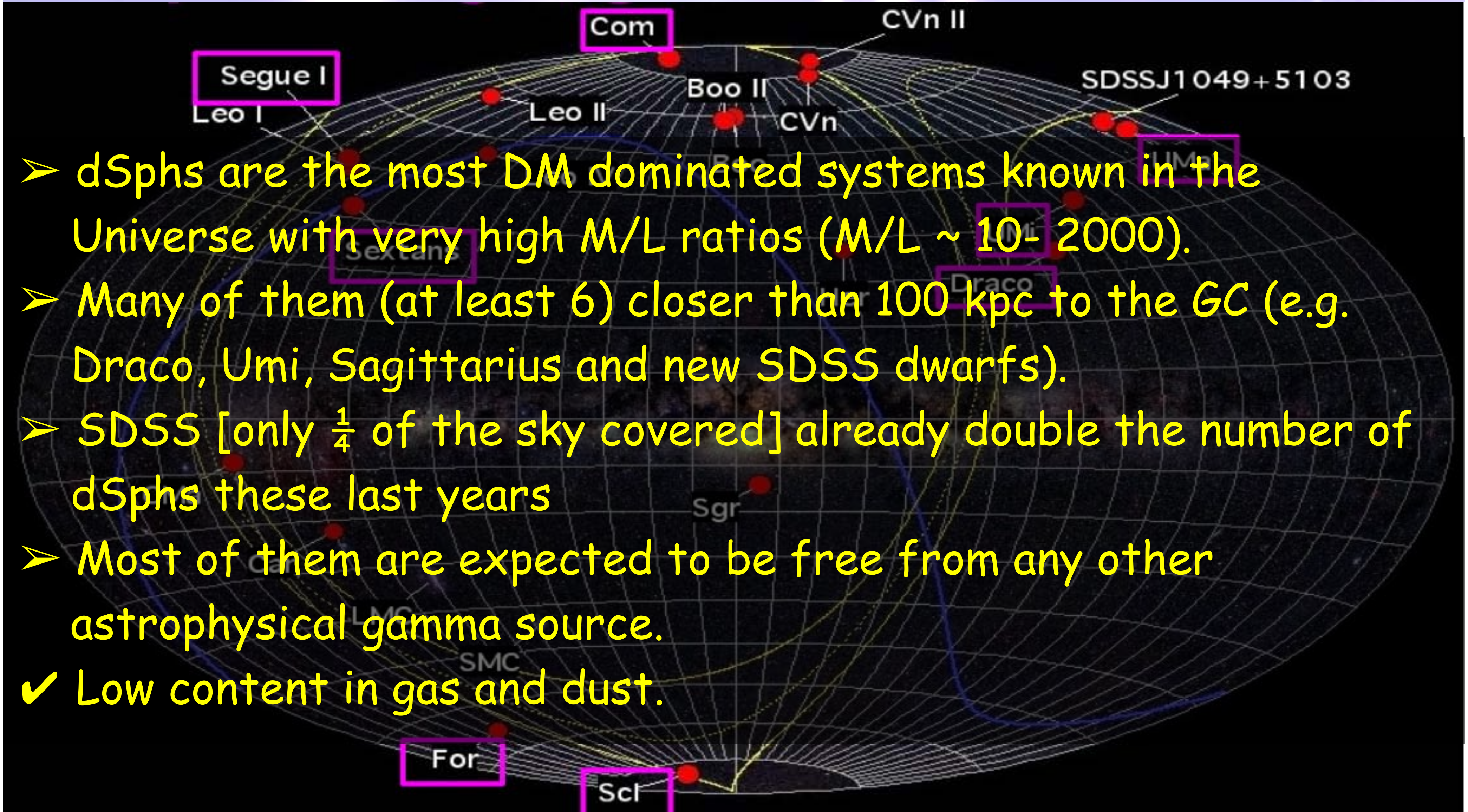


This model contains a Navarro-Frank-White DM component, annihilating in b-anti b, with mass = 40 GeV;
No structure left in the residuals at 1.5-6 GeV

Dwarf spheroidal galaxies (dSph) : promising targets for DM detection



Dwarf spheroidal galaxies (dSph) : promising targets for DM detection



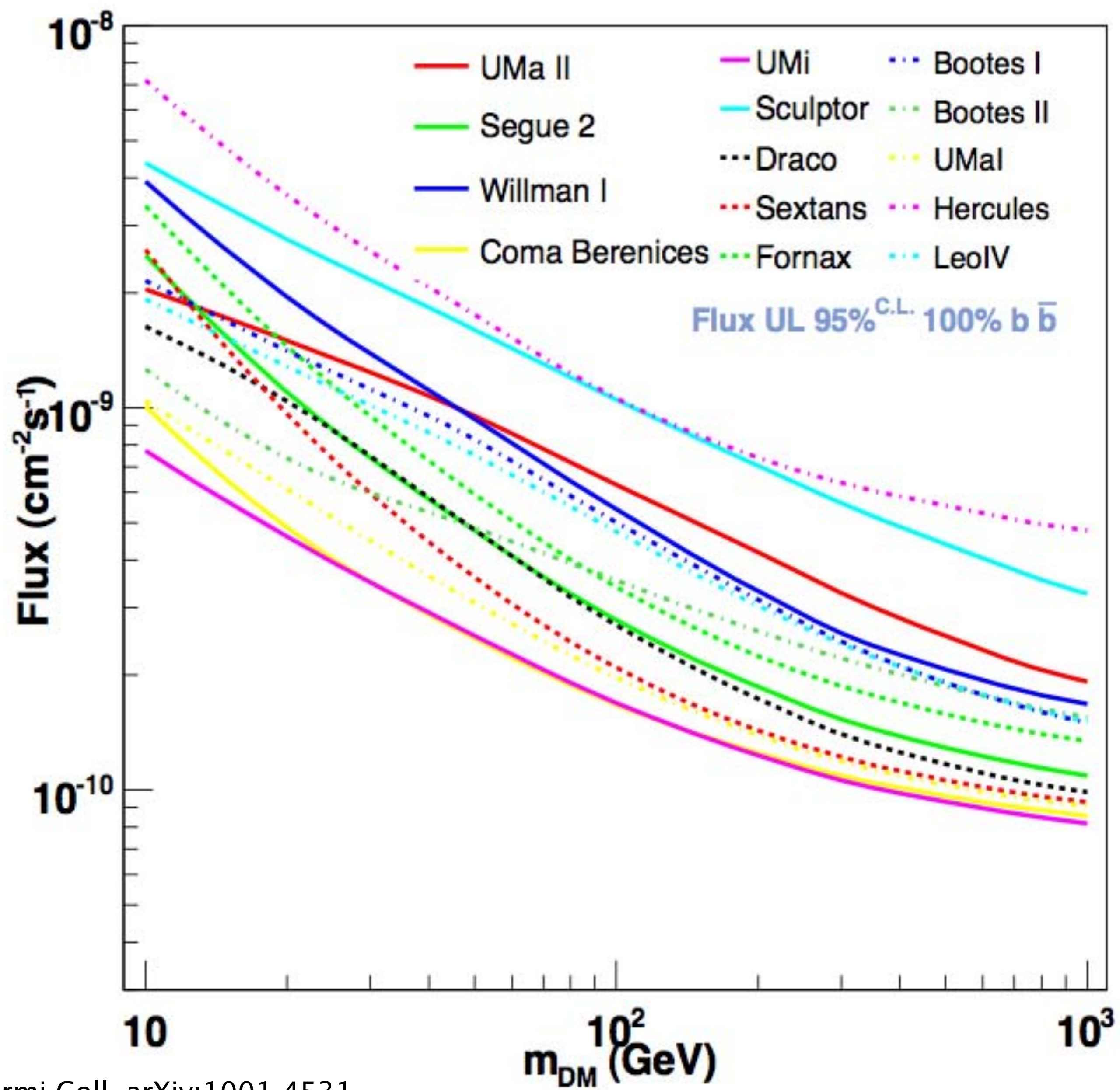
- dSphs are the most DM dominated systems known in the Universe with very high M/L ratios (M/L ~ 10- 2000).
- Many of them (at least 6) closer than 100 kpc to the GC (e.g. Draco, Umi, Sagittarius and new SDSS dwarfs).
- SDSS [only $\frac{1}{4}$ of the sky covered] already double the number of dSphs these last years
- Most of them are expected to be free from any other astrophysical gamma source.
- ✔ Low content in gas and dust.

Dwarf Spheroidal Galaxies upper-limits

No detection by Fermi with 11 months of data. 95% flux upper limits are placed for several possible annihilation final states.

- Flux upper limits are combined with the DM density inferred by the stellar data(*) for a subset of 8 dSph (based on quality of stellar data) to extract constraints on $<\sigma v>$ vs WIMP mass for specific DM models

(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)



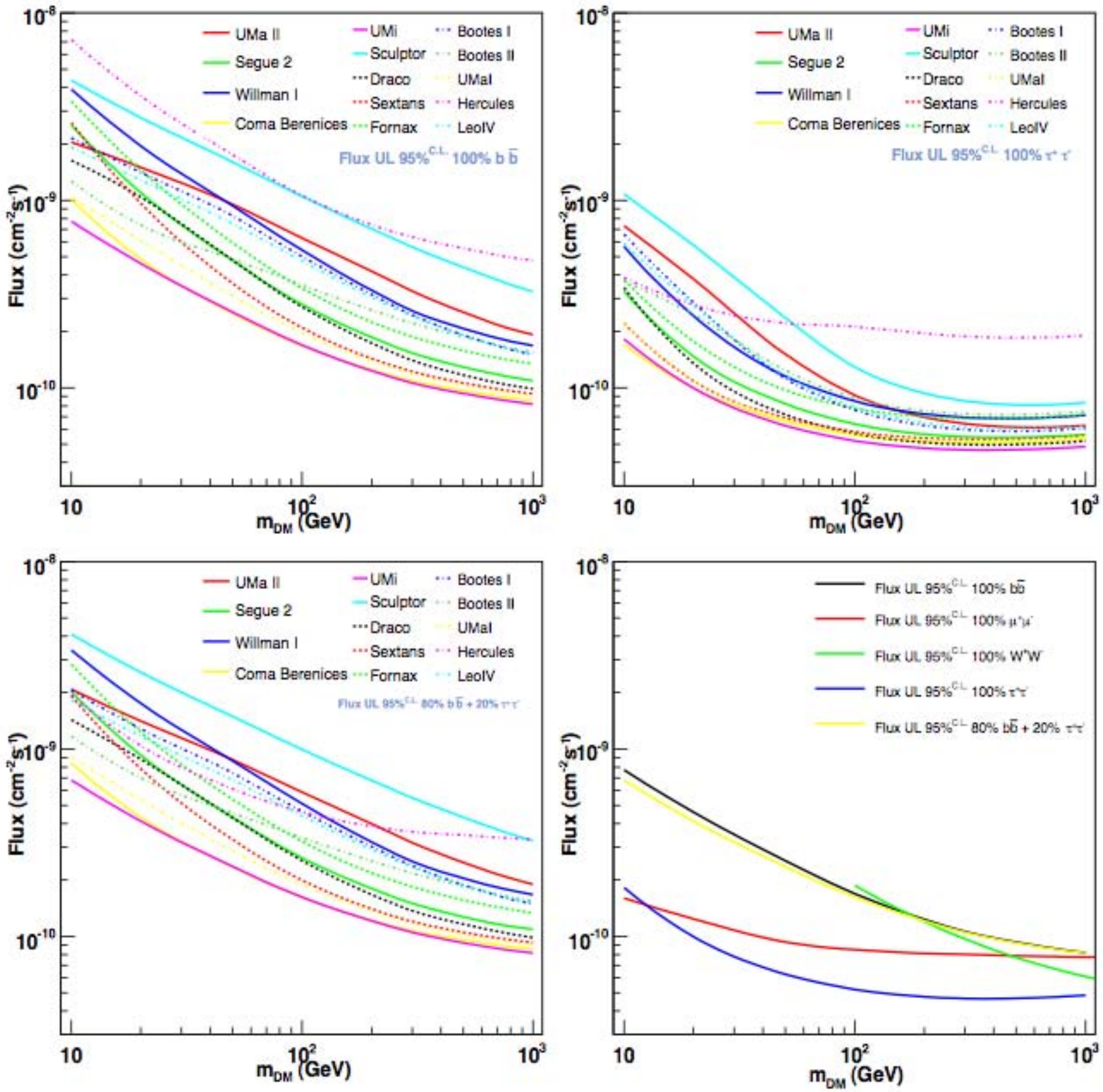
Fermi Coll. arXiv:1001.4531

Dwarf Spheroidal Galaxies upper-limits

No detection by Fermi with 11 months of data. 95% flux upper limits are placed for several possible annihilation final states.

- Flux upper limits are combined with the DM density inferred by the stellar data(*) for a subset of 8 dSph (based on quality of stellar data) to extract constraints on < σv> vs WIMP mass for specific DM models

(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)



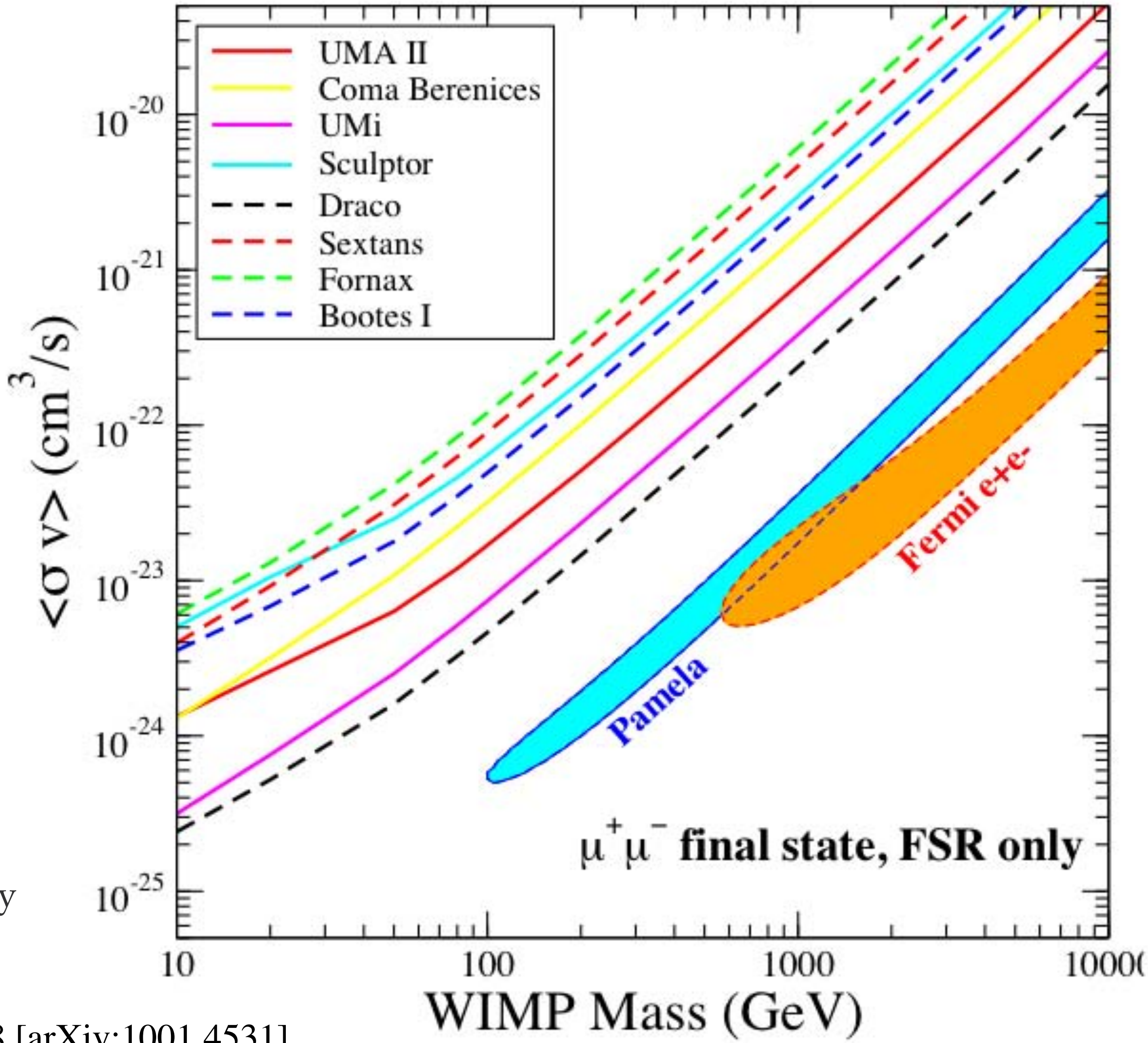
Fermi Coll. arXiv:1001.4531

Dwarf Spheroidal Galaxies upper-limits

No detection by Fermi with 11 months of data. 95% flux upper limits are placed for several possible annihilation final states.

- Flux upper limits are combined with the DM density inferred by the stellar data(*) for a subset of 8 dSph (based on quality of stellar data) to extract constraints on < σv> vs WIMP mass for specific DM models

(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)



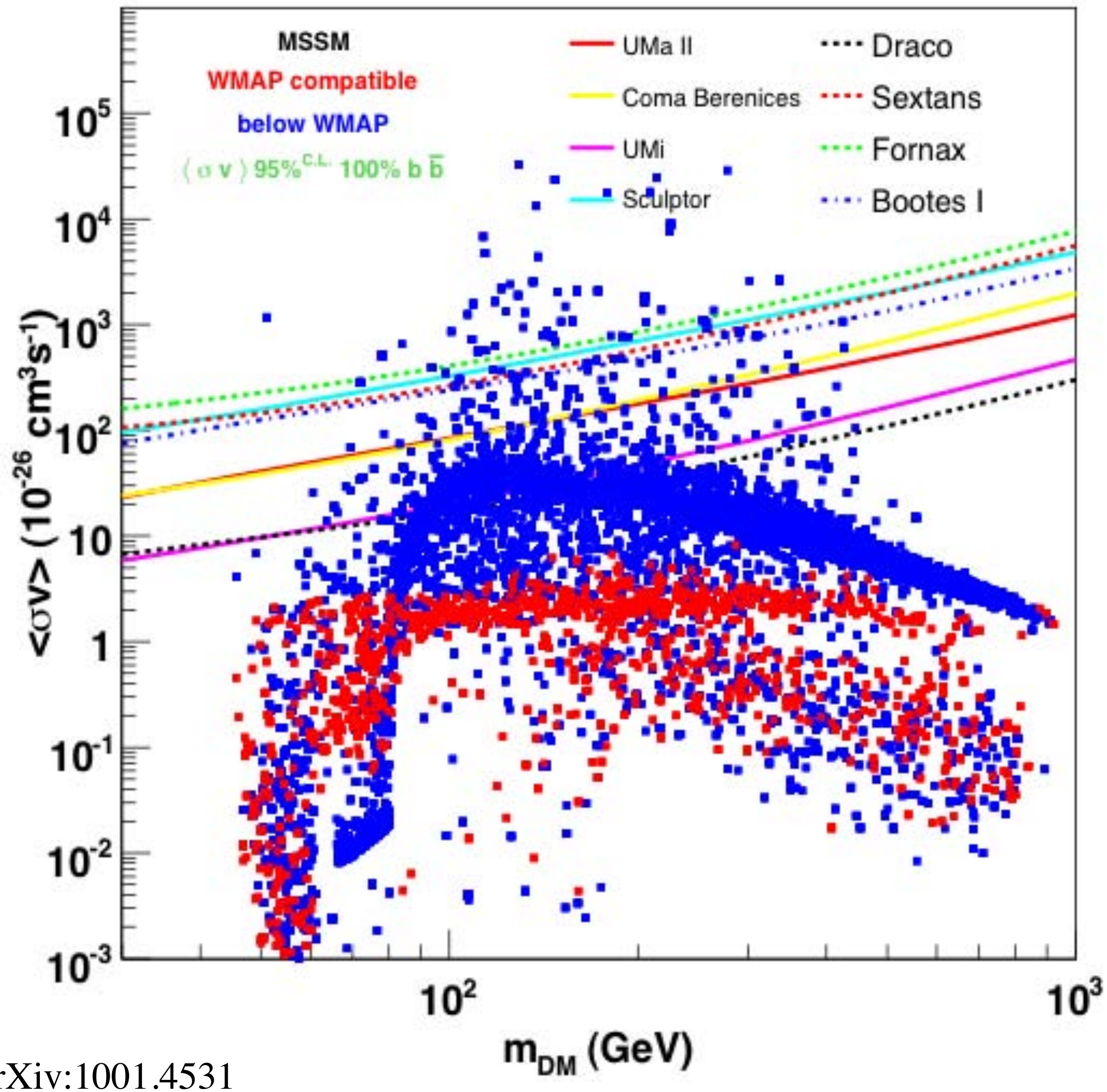
Fermi Coll. ApJ 712 (2010) 147-158 [arXiv:1001.4531]

Dwarf Spheroidal Galaxies upper-limits

No detection by Fermi with 11 months of data. 95% flux upper limits are placed for several possible annihilation final states.

- Flux upper limits are combined with the DM density inferred by the stellar data(*)for a subset of 8 dSph (based on quality of stellar data) to extract constraints on < σv> vs WIMP mass for specific DM models

(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)



Fermi Coll. ApJ 712 (2010) 147-158 arXiv:1001.4531

Inverse Compton Emission and Diffusion in Dwarfs

- We expect significant IC gamma-ray emission for high mass WIMP models annihilating to leptonic final states.
- The IC flux depends strongly on the uncertain/unknown diffusion of cosmic rays in dwarfs.
- We assume a simple diffusion model similar to what is found for the Milky Way

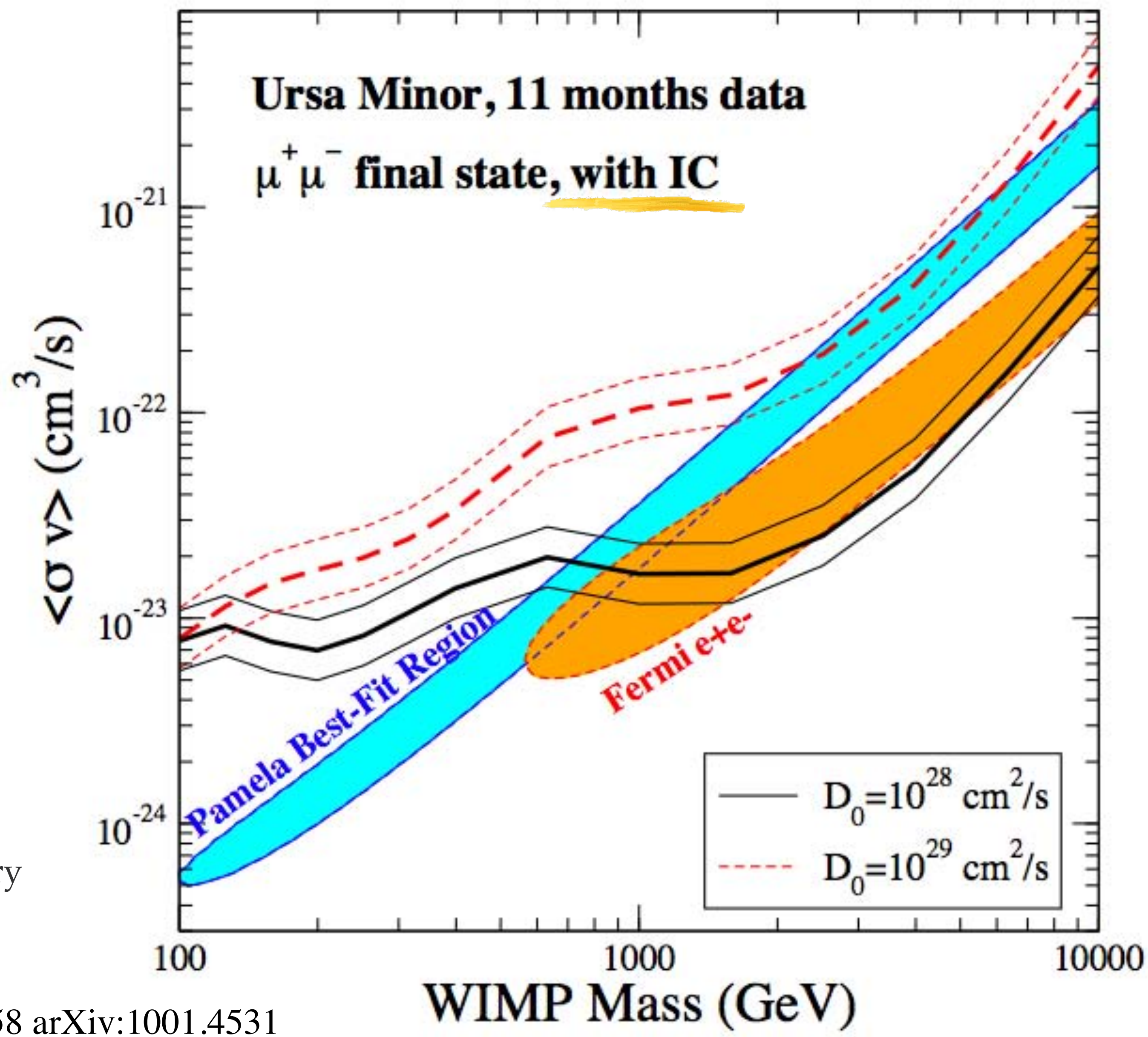
$D(E) = D_0 E^{1/3}$ with $D_0 = 10^{28}$ cm^2/s

(only galaxy with measurements, scaling to dwarfs ??)

Dwarf Spheroidal Galaxies upper-limits

Exclusion regions already cutting into interesting parameter space for some WIMP models

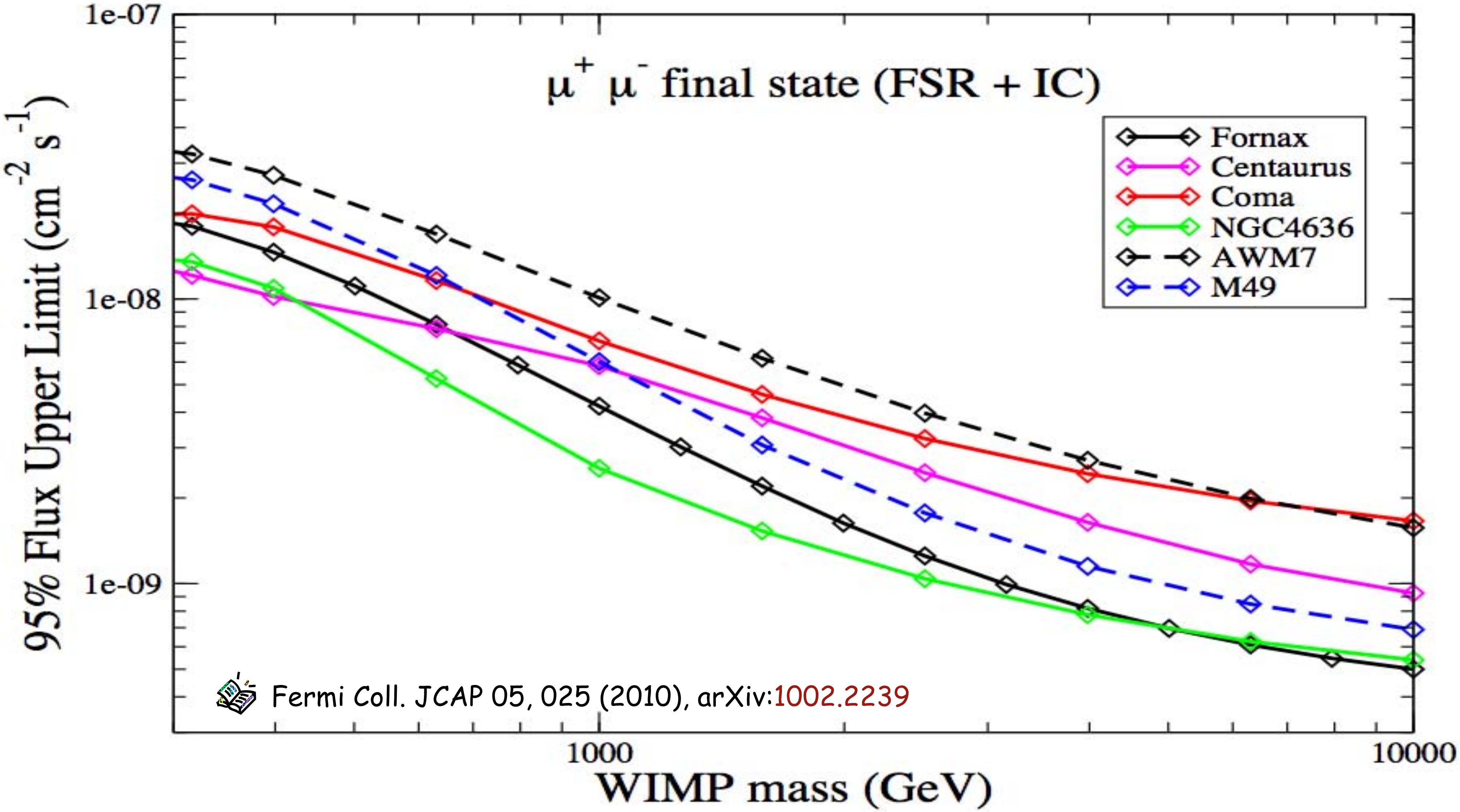
Stronger constraints can be derived if IC of electrons and positrons from DM annihilation off of the CMB is included, however diffusion in dwarfs is not known ⇒ use bracketing values of diffusion coefficients from cosmic rays in the Milky Way



(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)

Fermi Coll. ApJ 712 (2010) 147-158 arXiv:1001.4531

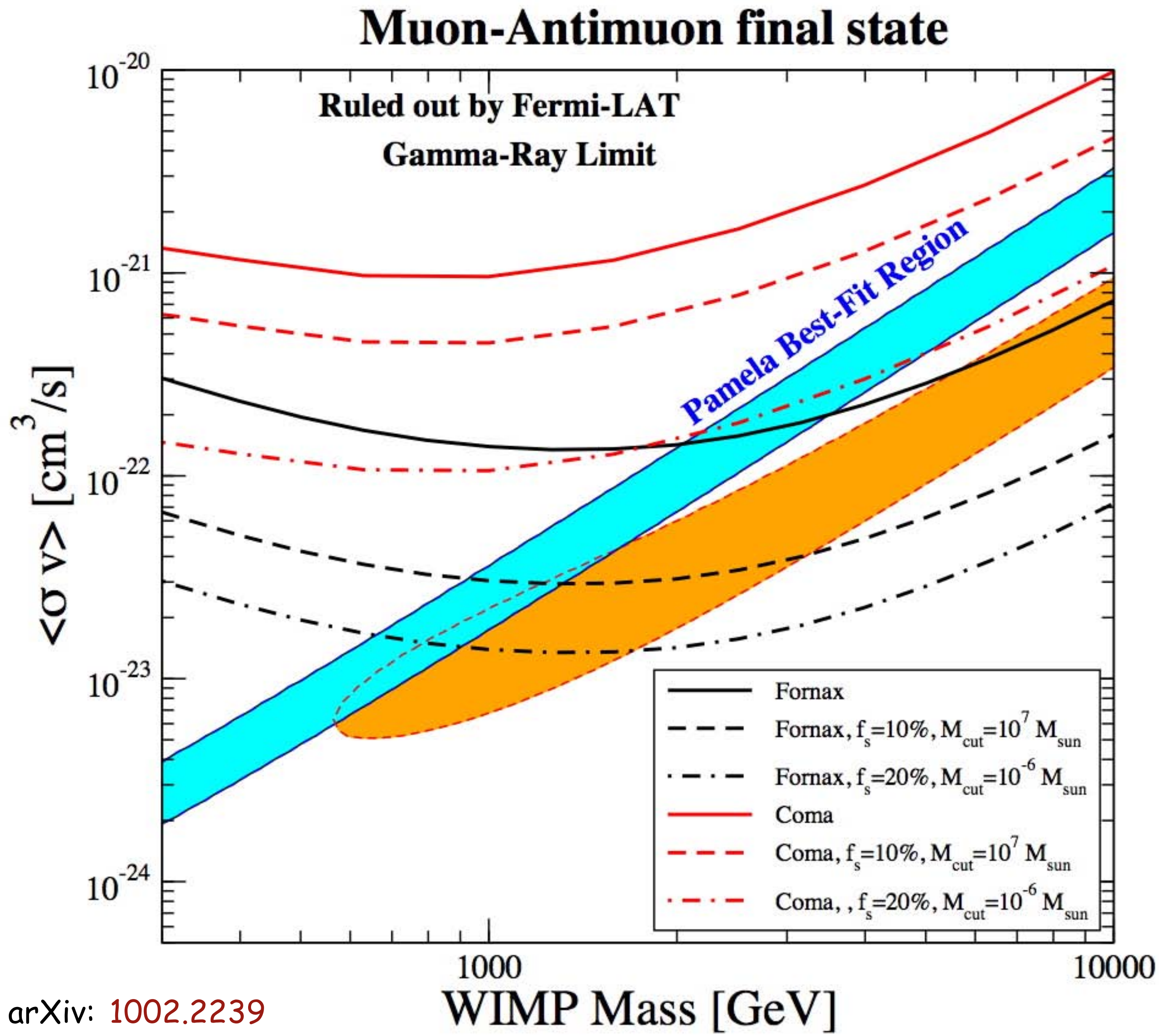
Galaxy Clusters upper-limits



Flux upper limits as a function of particle mass for an assumed μ+μ- final state, including the contributions of both FSR and IC gamma-ray emission

Galaxy Clusters upper-limits

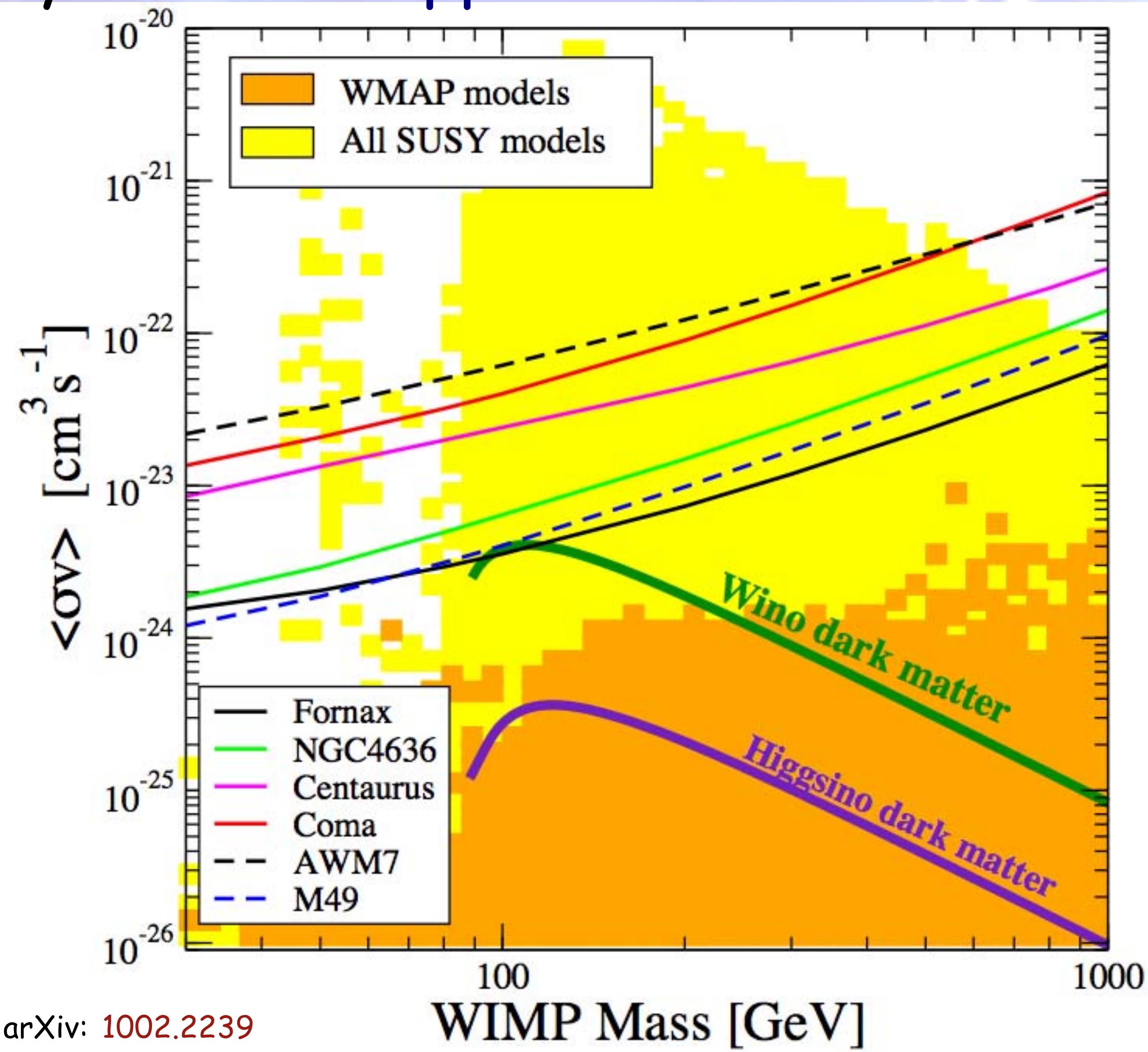
Stronger constraints on leptophilic DM models can be derived with galaxy clusters when the IC contribution off the CMB of secondary electrons (from DM annihilation) is included



Fermi Coll. JCAP 05, 025 (2010), arXiv: 1002.2239

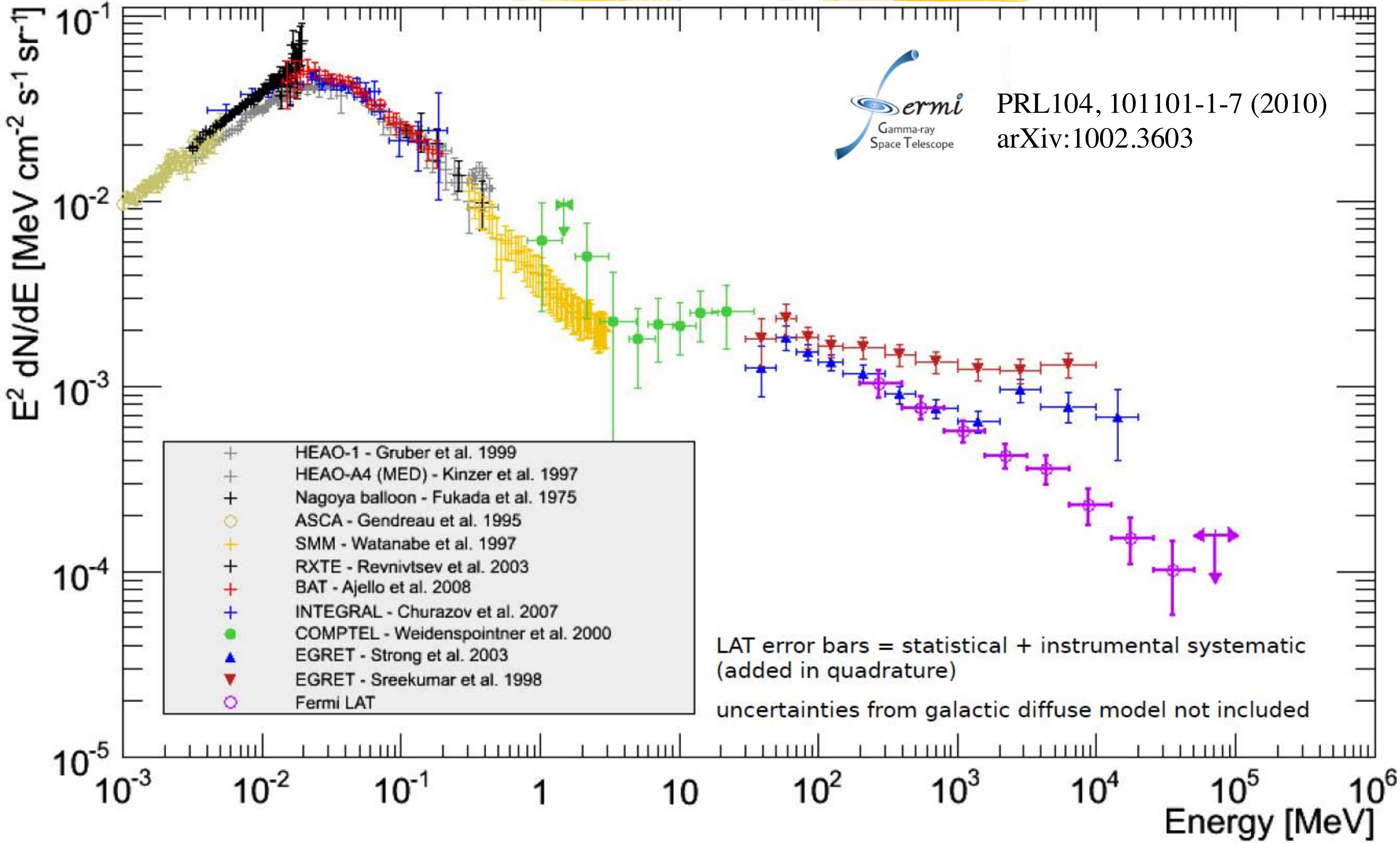
Galaxy Clusters upper-limits

- Constraints for a b-bbar final state are weaker than or comparable to (depending on the assumption on substructures) the ones obtained with dSph

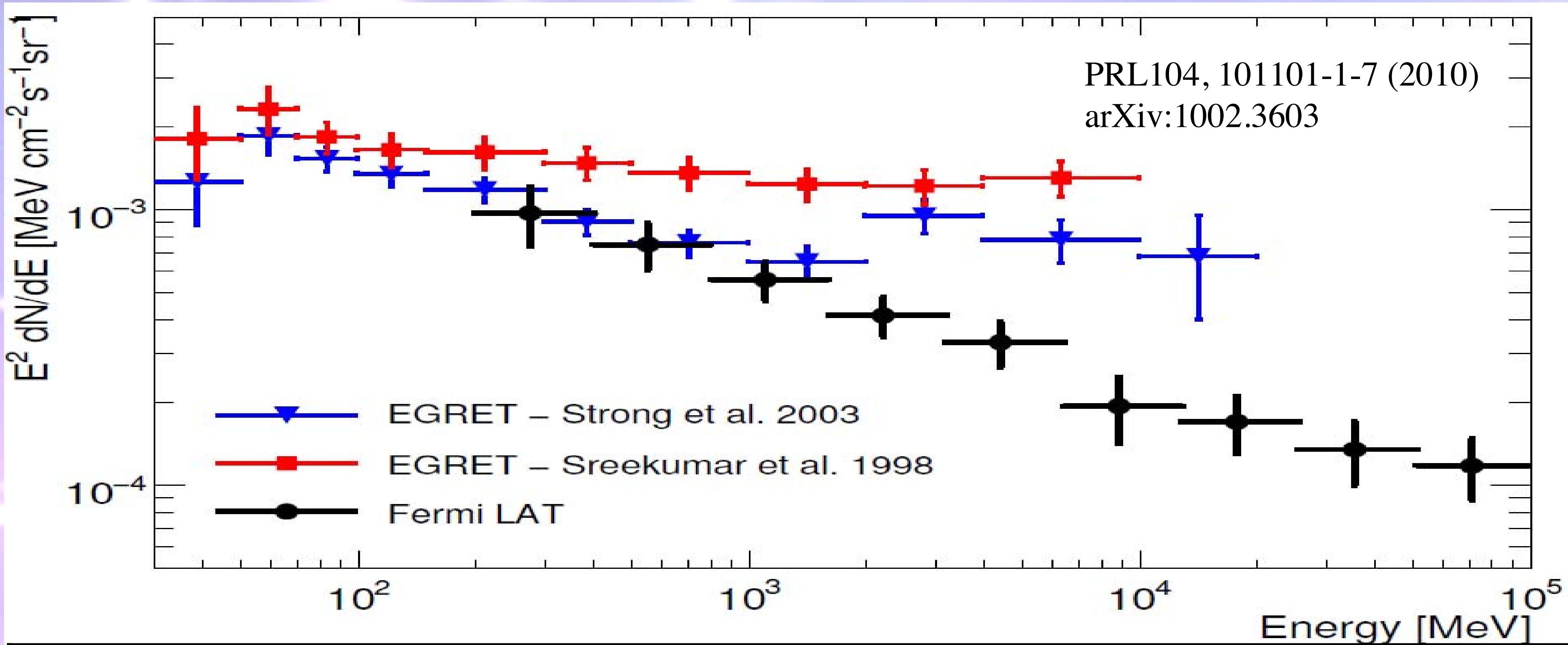


Fermi Coll. JCAP 05, 025 (2010), arXiv: 1002.2239

SED of the isotropic diffuse emission (1 keV–100 GeV)

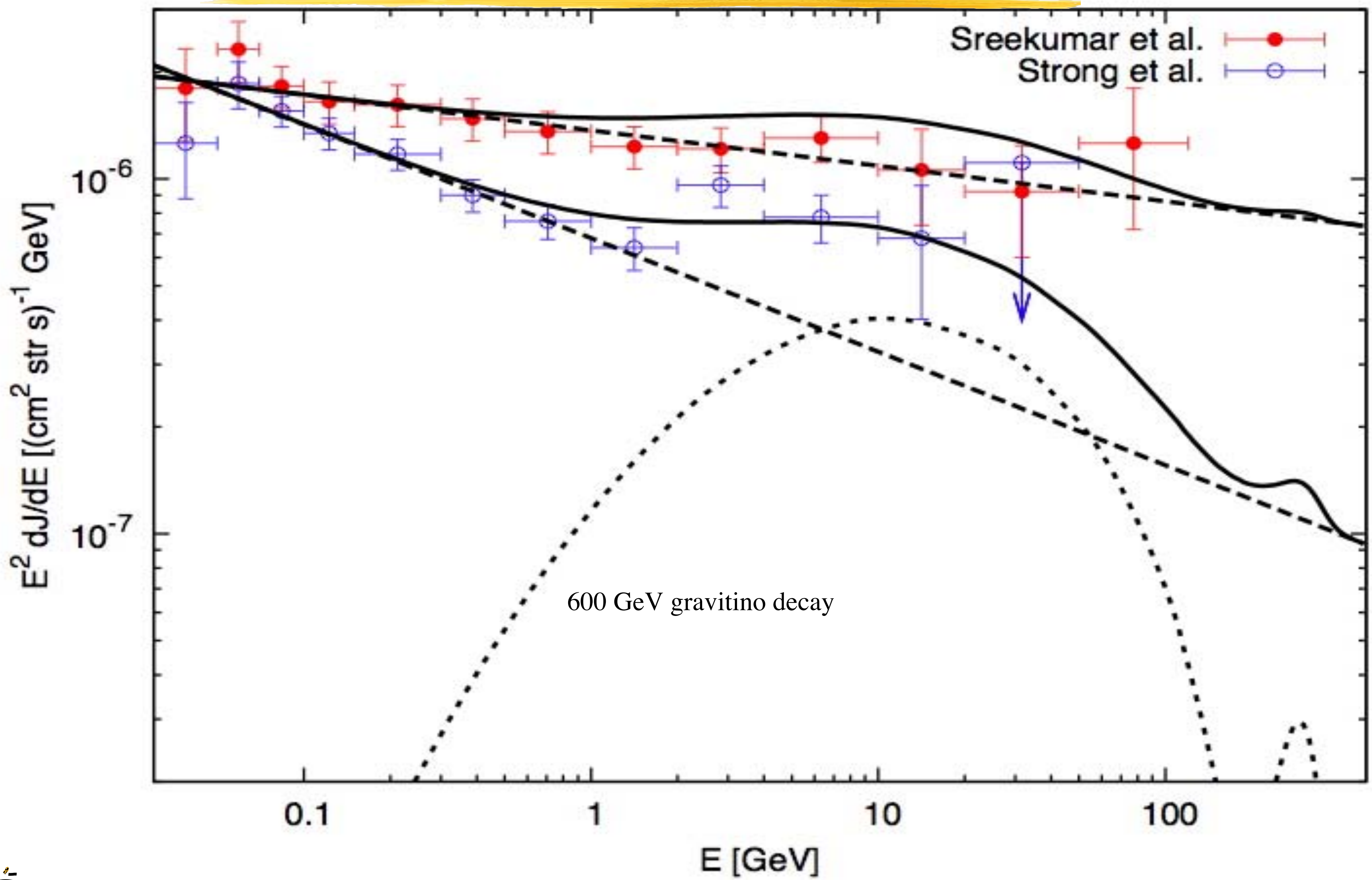


SED of the isotropic diffuse emission (1 keV–100 GeV)



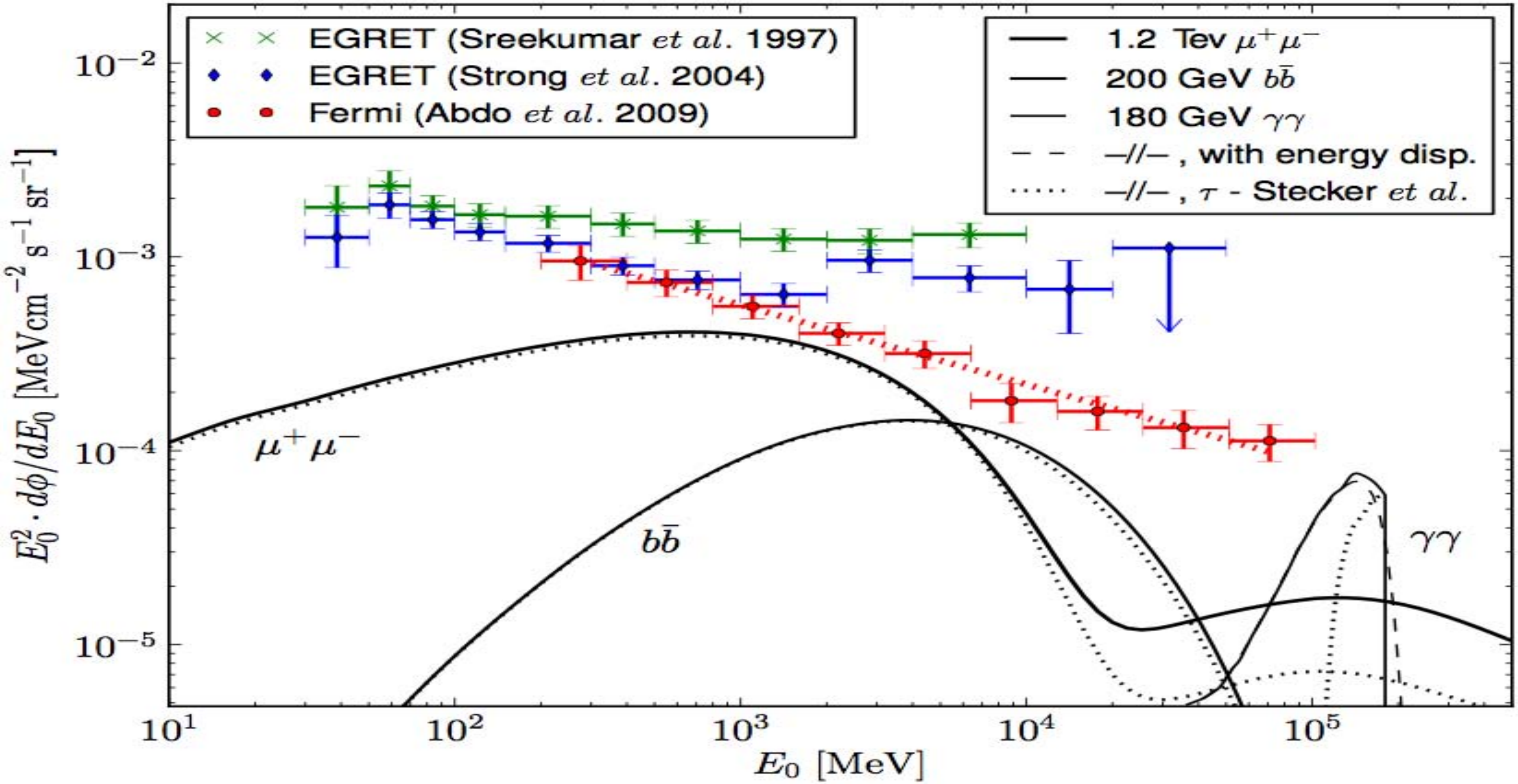
	Flux, E>100 MeV	spectral index
Fermi LAT	**1.03 +/- 0.17**	**2.41 +/- 0.05**
EGRET (Sreekumar et al., 1998)	1.45 +/- 0.05	2.13 +/- 0.03
EGRET (Strong et al. 2004)	1.11 +/- 0.10	
LAT + resolved sources below EGRET sensitivity	1.19 +/- 0.18	2.37 +/- 0.05
	x 10^{-5} cm^{-2} s^{-1} sr^{-1}	

extragalactic gamma-ray spectrum



W. Buchmüller, A. Ibarra, T. Shindou, F. Takayama, D. Tranl, arXiv:0906.1187

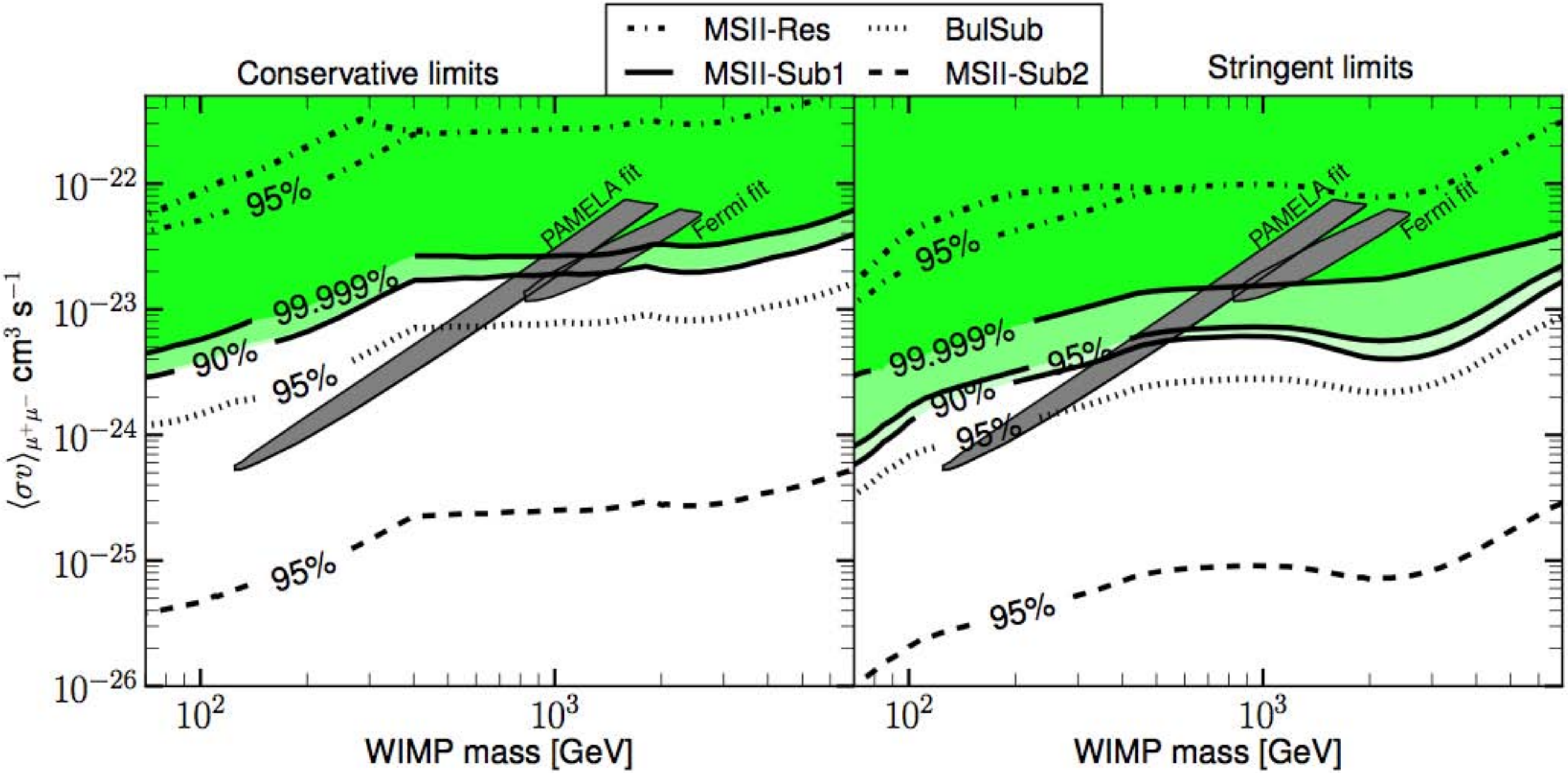
extragalactic gamma-ray spectrum



Fermi Coll. JCAP 04 (2010) 014 arXiv:1002.4415

others possible contributions to the extragalactic gamma-ray spectrum

extragalactic gamma-ray spectrum

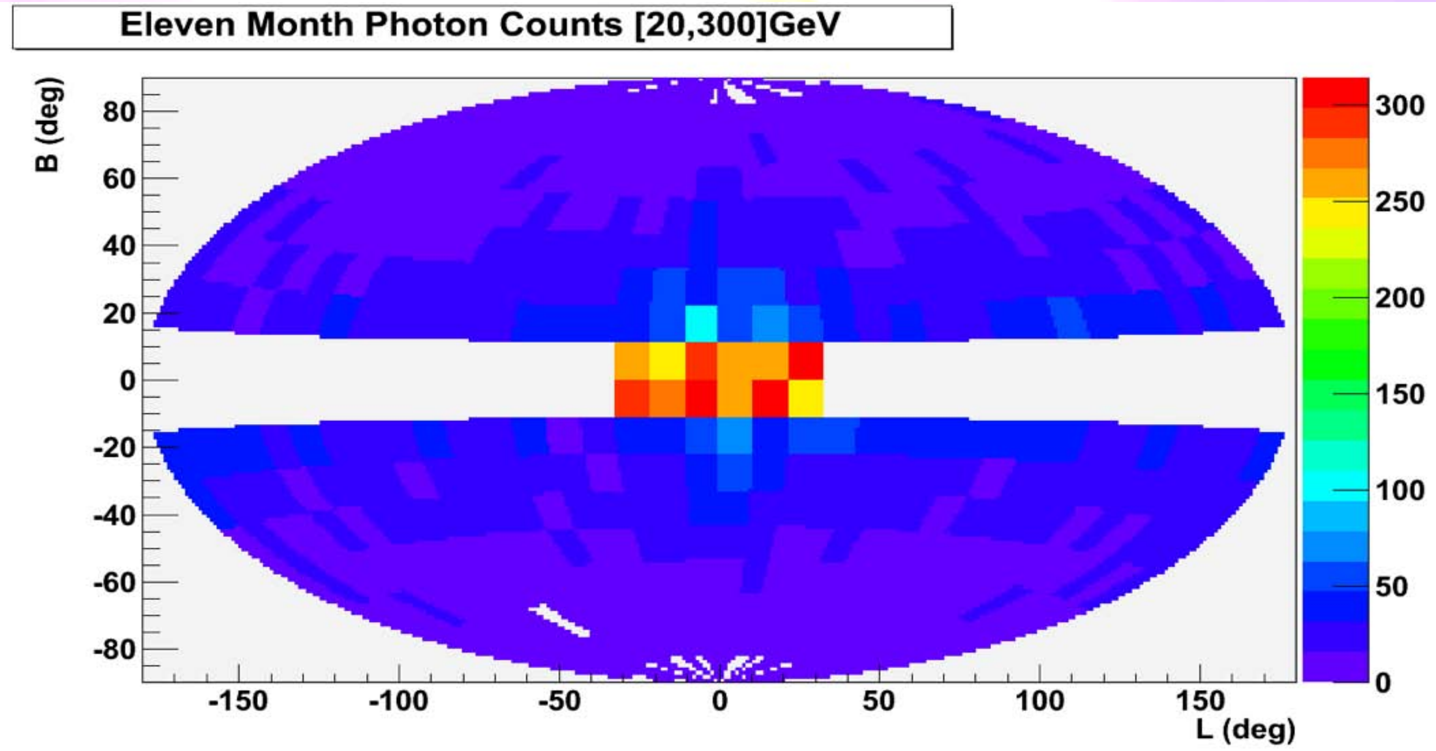


Fermi Coll. JCAP 04 (2010) 014 arXiv:1002.4415

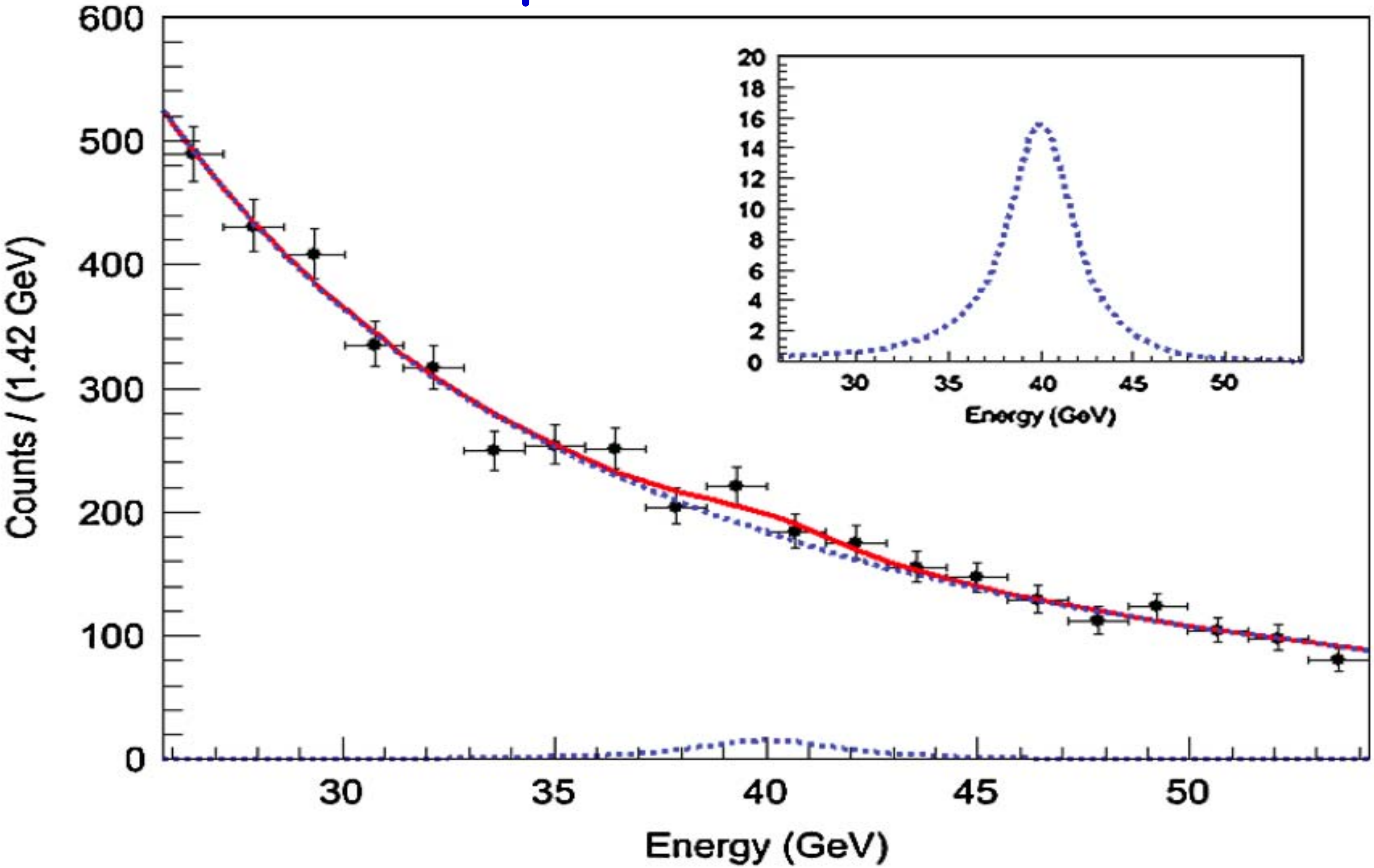
limits on dark matter annihilation into μ+μ— final states

Search for Spectral Gamma Lines

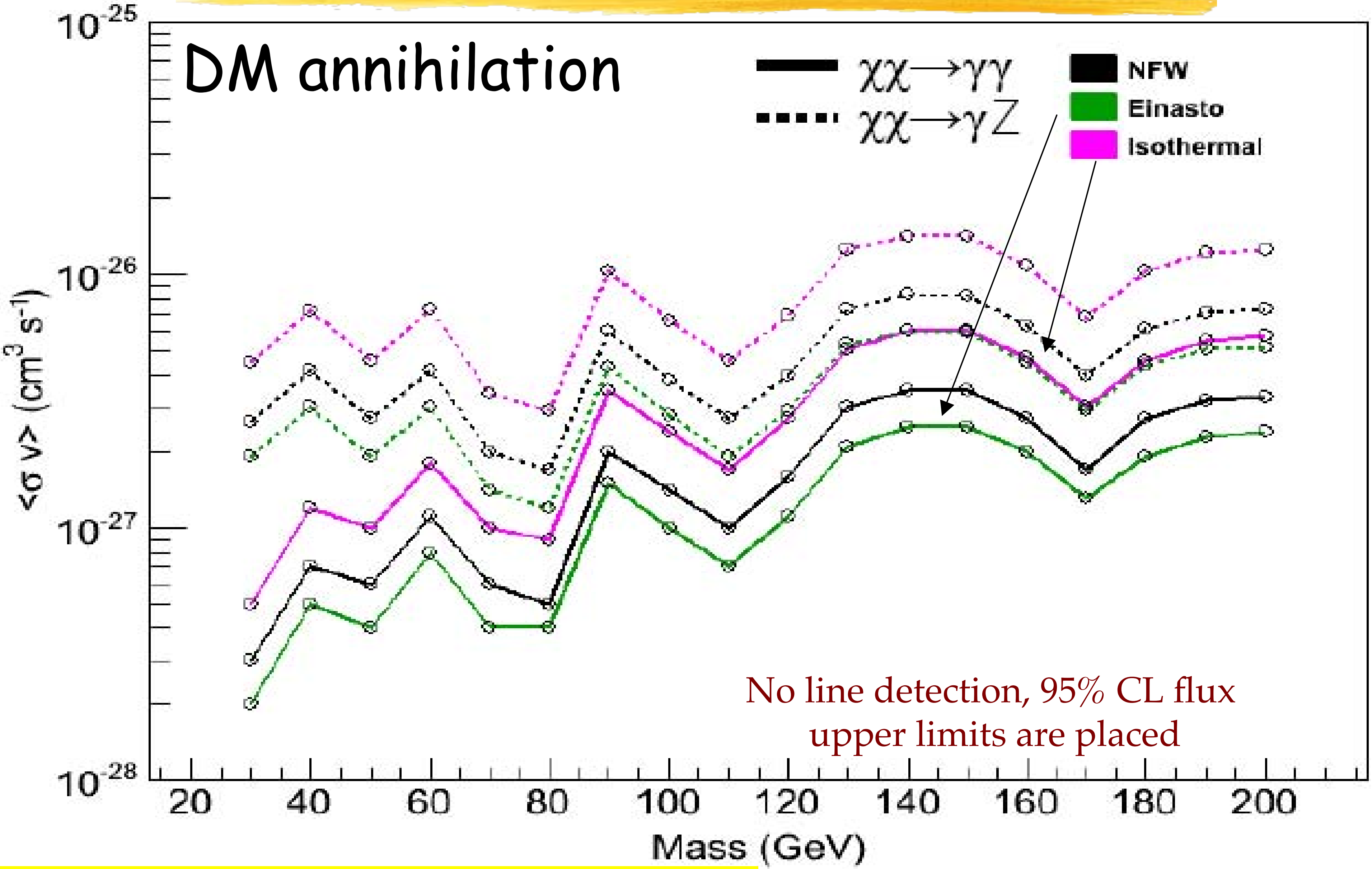
- Smoking gun signal of dark matter
- Search for lines in the first 11 months of Fermi data in the 30-200 GeV energy range
- Search region
  - $|b|>10^{\circ}$ and 30° around galactic center
- Remove point sources (for $|b|>1^{\circ}$). The data selection includes additional cuts to remove residual charged particle contamination.



Wimp lines search

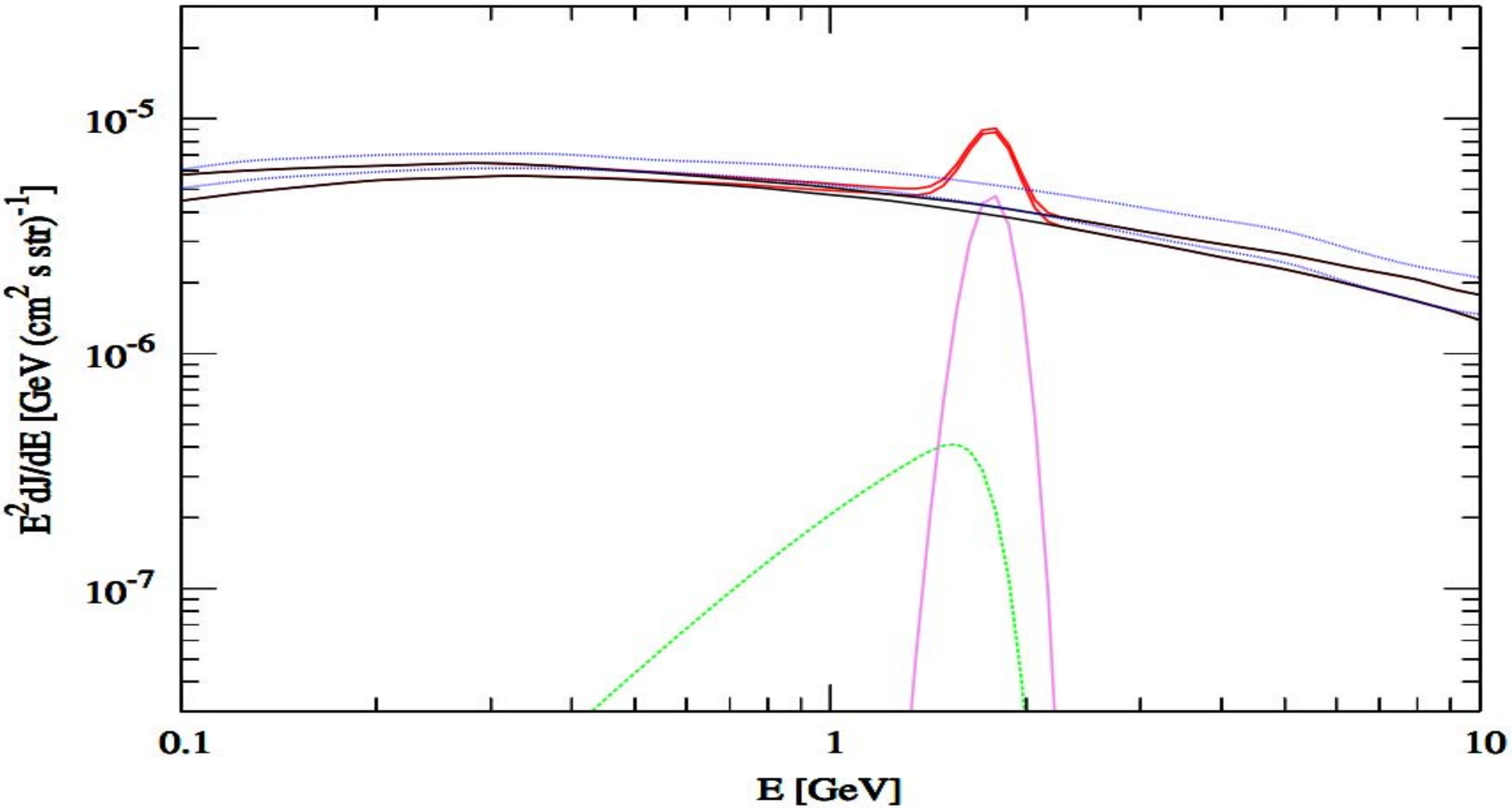


Search for Spectral Gamma Lines



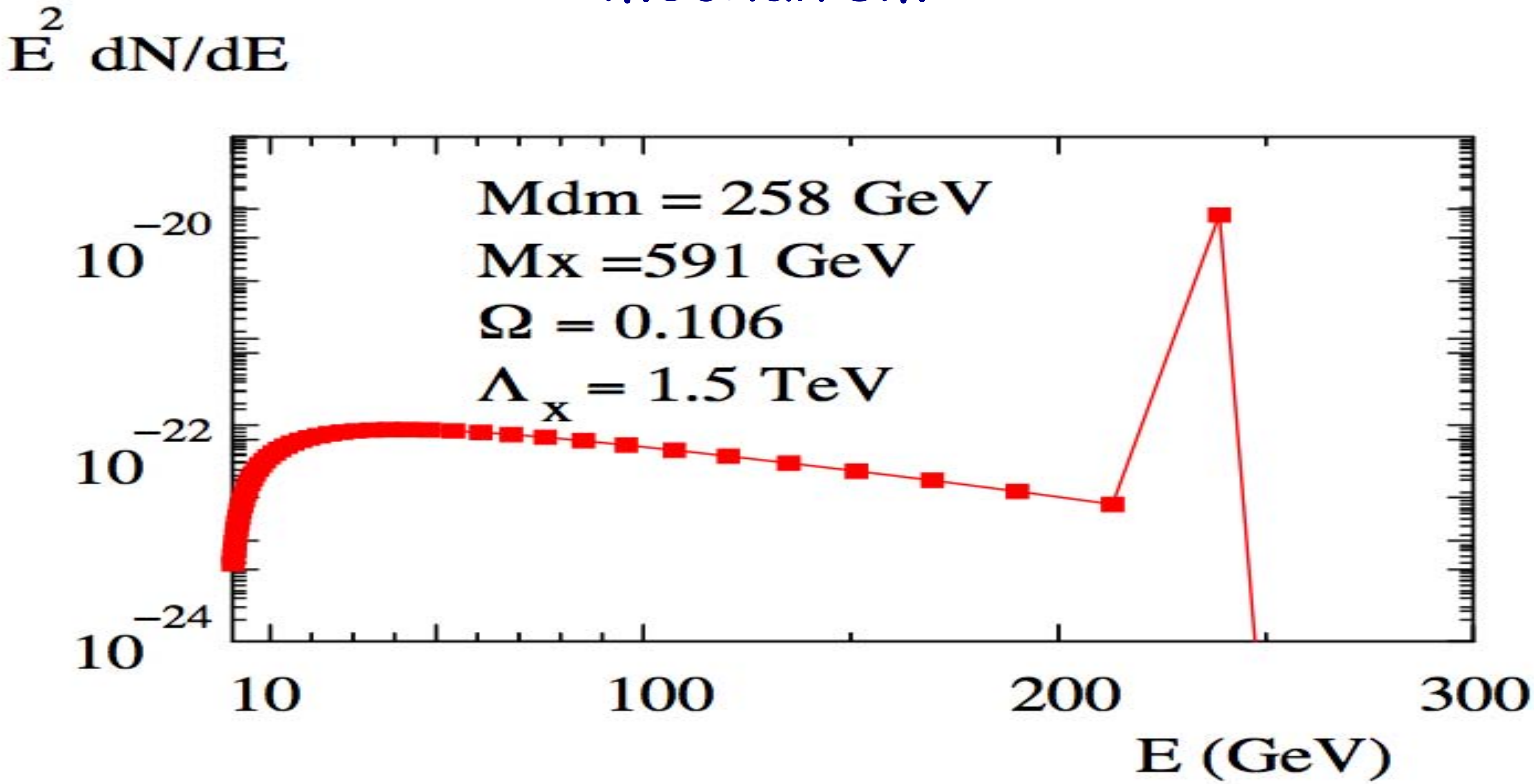
Fermi LAT Coll. PRL 104, 091302-08 (2010), arXiv:1001.4836

Gamma-ray detection from gravitino dark matter decay in the μνSSM



Ki-Young Choi, Daniel E.Lopez-Fogliani, Carlos Munoz, Roberto Ruiz de Austri, arXiv:0906.3681

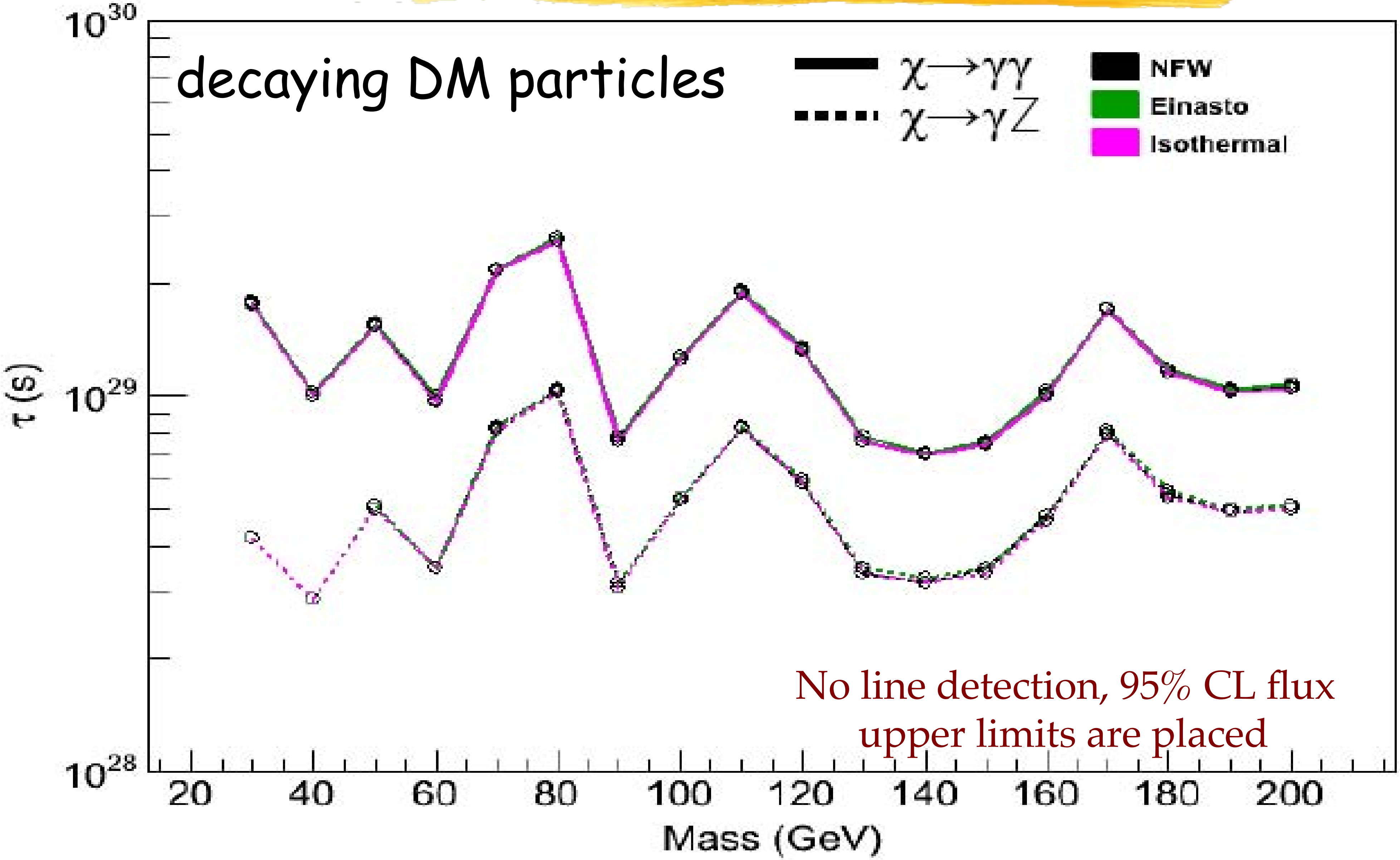
Gamma ray line generated by the Green-Schwarz mechanism



example of gamma-ray flux respecting WMAP constraint for a DM mass of 258 GeV

Y. Mambrini JCAP [arXiv:0912:005, 2009]

Search for Spectral Gamma Lines



Fermi LAT Coll. PRL 104, 091302-08 (2010), arXiv:1001.4836

Conclusion

- **PAMELA has been in orbit and studying cosmic rays for ~42 months. >10^9 triggers registered and >18 TB of data has been down-linked.**

- **Antiproton-to-proton flux ratio and antiproton energy spectrum (~100 MeV - ~200 GeV) show no significant deviations from secondary production expectations.**

- **High energy positron fraction (>10 GeV) increases significantly (and unexpectedly!) with energy. Primary source? Data at higher energies might help to resolve origin of rise (spillover limit ~300 GeV).**

- **e^- spectrum up to ~200 GeV shows spectral features that may point to additional components. Analysis is ongoing to increase the statistics and expand the measurement of the e^- spectrum up to ~500 GeV and e^+ spectrum up to ~300 GeV (all electrum ($e^- + e^+$) spectrum up to ~1 TV).**

- **Furthemore:**
  - **PAMELA is going to provide measurements on elemental spectra and low mass isotopes with an unprecedented statistical precision and is helping to improve the understanding of particle propagation in the interstellar medium**
  - **PAMELA is able to measure the high energy tail of solar particles.**
  - **PAMELA is going to set a new lower limit for finding Antihelium.**

Conclusion:

The Electron+positron spectrum (CRE) is significantly harder than previously thought on the basis of previous data

Adopting the presence of an extra e^+ primary component with ~ 1.5 spectral index and E_{cut} ~ 1 TeV allow to consistently interpret Fermi-LAT CRE data (improving the fit), HESS and PAMELA

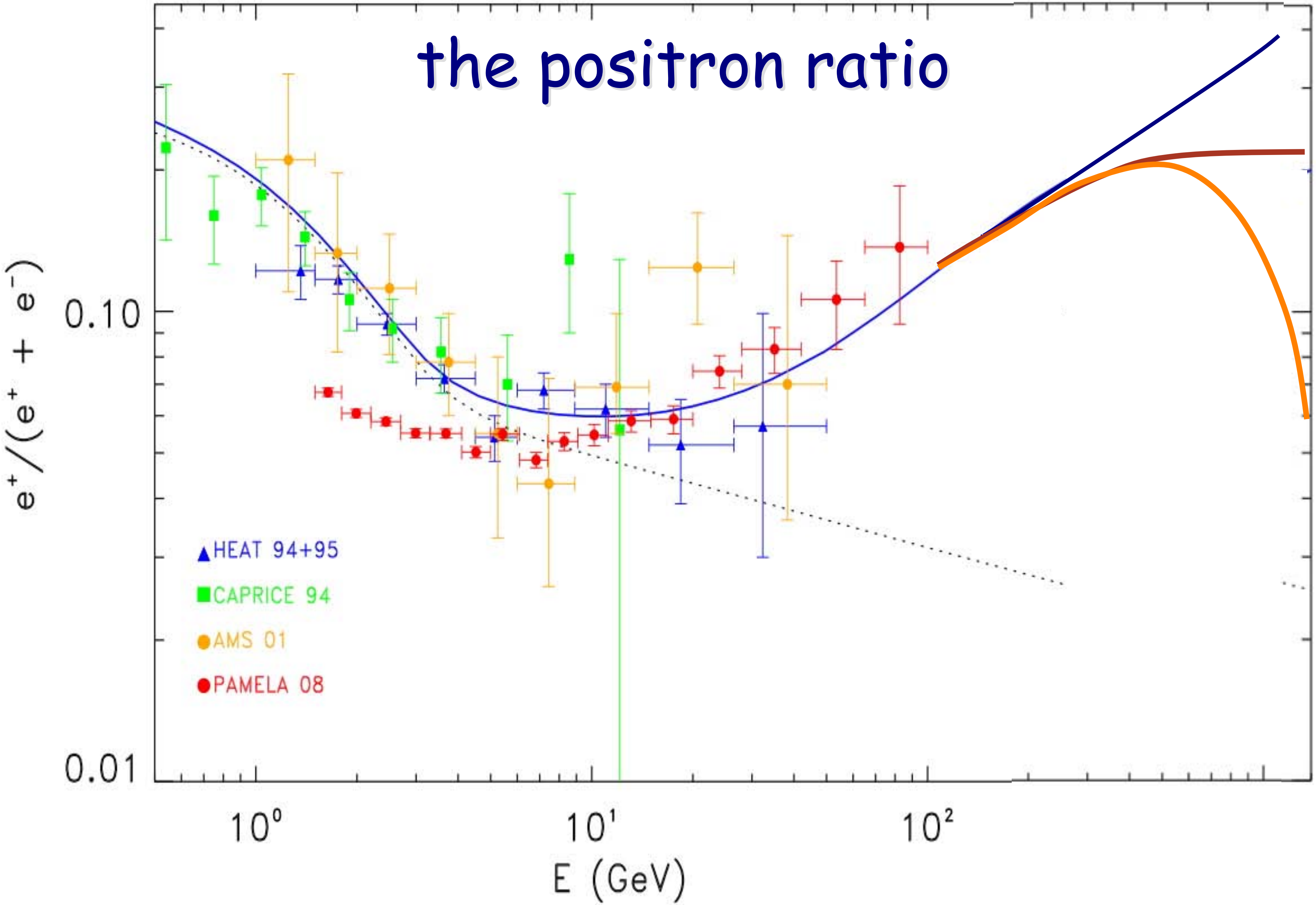
Such extra-component can be originated if the secondary production takes place in the same region where cosmic rays are being accelerated (to be tested with future B/C measurements)

- or by pulsars for a reasonable choice of relevant parameters (to be tested with future Fermi pulsars measurements)
- or by annihilating dark matter for model with $M_{DM} \approx 1$ TeV

- Improved analysis and complementary observations

(CRE **anisotropy**, spectrum and angular distribution of diffuse γ, DM sources search in γ) are required to possibly discriminate the right scenario.

the positron ratio



New Data is Forthcoming

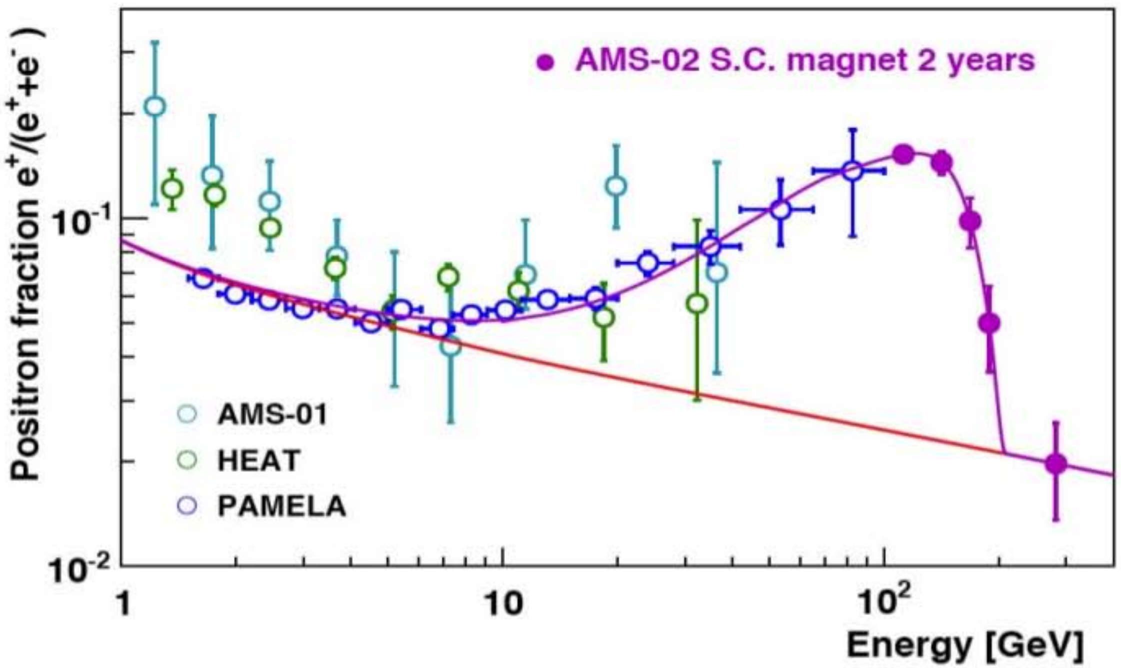
Electron Spectrum:

- **PAMELA & FERMI (GLAST)** (taking data in space);
- **ATIC-4** (had successful balloon flight,under analysis);
- **CREST** (new balloon payload under development);
- **AMS-02** (launch date TBD);
- **CALET** (proposed for ISS);
- **ECAL** (proposed balloon experiment).

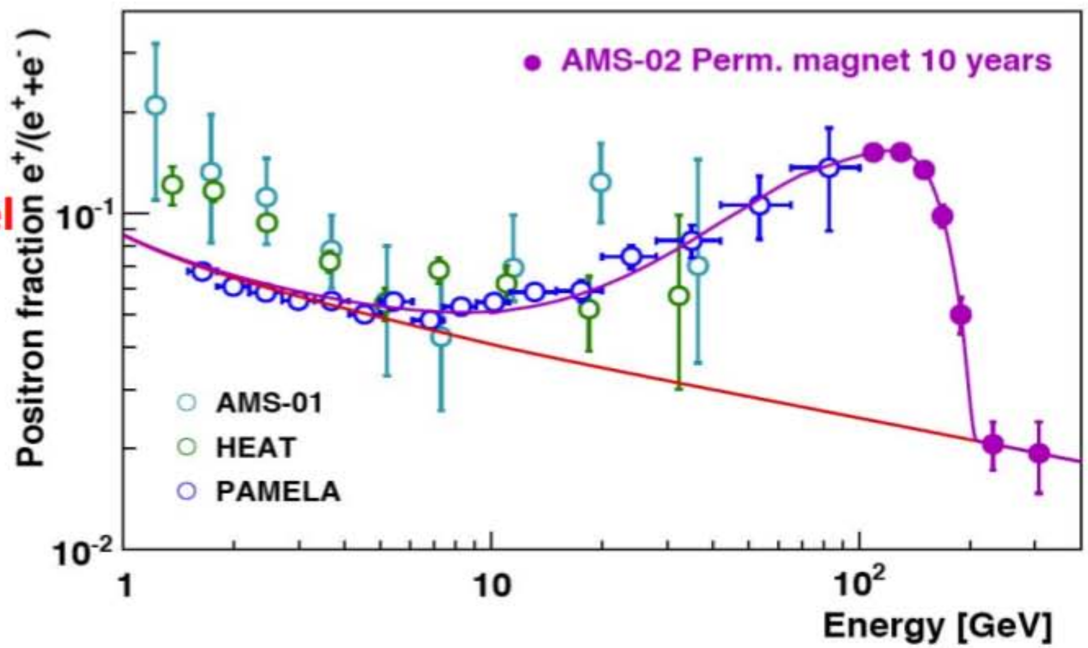
Comparison of High-Energy Electron Missions

Mission	Upper Energy (TeV)	Collecting Power ($m^2 sr$)	Calorimeter Thickness (X_0)	Energy Resolution (%)
CALET	20	0.75	30.8	< 3 (over 100 GeV)
PAMELA	0.25 (spectrometer) 2 (calorimeter)	0.0022 0.04	16.3	5.5 (300 GeV) 12 (300 GeV) 16 (1TeV)
GLAST	0.7	2.1 (100 GeV) 0.7 (700 GeV)	8.3	6 (100 GeV) 16 (700 GeV)
AMS-02	0.66 (spectrometer) 1 (calorimeter)	0.5 0.06 (100 GeV) < 0.04 (1 TeV)	16.0	< 3 (over 100 GeV)

Positron / Electron Separation: **PAMELA & AMS-02**



AMS sensitivity esponse to a 200 GeV
Dark Matter candidate in the e+e- channel



2nd Conclusion : Gamma

- No discovery (yet)....
- .... however promising constraints on the nature of DM have been placed
- In addition to increased statistics, better understanding of the astrophysical and instrumental background will improve our ability to reliably extract a potential signal of new physics or set stronger constraints
- Further improvements are anticipated for analysis that benefits from multi-wavelength observations (for example galactic center, dwarf spheroidal galaxies and DM satellites)